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TESTS OF CEMENT MORTAR MIXED WITH VARIOUS KINDS OF SAND.

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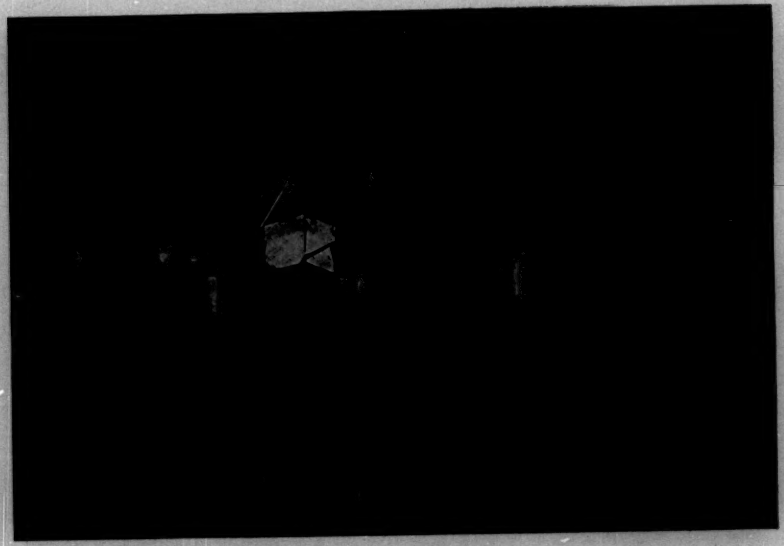
During the construction of a mining casemate at Fort Pulaski last year, the question arose as to the advisability of using fine beach sand instead of coarse river sand, on account of the greater cost of obtaining the latter. The writer took the position that the fine sand would be nearly as good, in fact good enough, and as its employment was estimated to save at least $1,000 in the total cost of the work. A short series of experiments was made, which, to the astonishment of all connected with the work, proved the fine sand to be slightly stronger than the coarse. These results were published in *Engineering News,* with some others on the effect of small percentages of mud and on the use of salt water instead of fresh. These results were mentioned by the editor as being opposed to those obtained by all previous experimenters, and this fact induced the author to

investigate the question in a more thorough and scientific manner.

The first matter to be settled was the method of working in order to eliminate as many uncertainties as possible. Where close figures are to be expected, a slight inaccuracy in the work might lead to erroneous conclusions. After looking over all of the different methods, the following were finally adopted as being the most suitable for this work:

Methods of Conducting the Work.—The sand was first graded by means of 13 sieves, ranging from 8 to 140 wires to the lineal inch, and the grades indicated by the 2 sieves used. The grade 8–12, for example, means that the sand in this grade passed a sieve with 8 wires to the inch, and was held by one with 12 wires. (See Table No. 2). It was concluded to mix the mortar rather dry, about the consistency of moist snow, so as to be able to handle the briquettes immediately after moulding them. It was also believed that a dry mortar would give more even results under uniform pressure than a wet one. The sand and cement were first carefully weighed, then they were mixed dry by means of a square box with a rod run through the corners, after the manner of Gen. Q. A. Gillmore's concrete mixer. The water was measured with a graduated glass, and mixed into the cement and sand on a stone table with a trowel. If the mortar appeared too dry, more water was added; and if too wet, note was made of the fact, and the set proceeded with. In nearly all cases enough mortar was made at one mixing to make 8 briquettes. Four of these were broken at the end of a week, and the remainder in 8 weeks. As a difference of 1 per cent. of water in the finished mortar, could not, in all cases, be detected, a series of tests was made (Table No. 6) to determine the effect of such variations. The results proved conclusively that slight variations in the amount of water might cause considerable differences. In drawing conclusions, therefore, the percentage of water used must be considered.

It should also be borne in mind that some cements and some sands of the same size, require more water than others to yield a mortar of the same consistency. Generally speak-



SCALES, MORTAR-MIXER, TESTING-MACHINE, AND PRESS. TESTS OF CEMENT MORTAR MIXED WITH VARIOUS KINDS OF SANDS.

ing, fine sand requires more water than coarse, and natural cements more than Portlands. The briquettes were moulded in brass moulds of the form recommended by the committee of the American Society of Civil Engineers, in 1885, but were not pressed in by hand as recommended by this committee. The method used by Prof. Chas. D. Jameson was adopted. Prof. Jameson put his mortar into the moulds under a uniform pressure of 150 pounds per square inch, while in this work 200 pounds was used. The press consisted of a simple lever attached firmly to the wall by two long strap hinges, arranged at the proper height above a stone table. The brass mould was placed under this lever at a fixed distance from the hinge, and with a board on top of it having a hole cut in it the exact shape of a briquette. The mould and the hole in the board was then filled with loose mortar, and the lever applied to press the loose mortar into the mould. The piece that was cut out of this hole (with a scroll saw) was fastened to a square stick and arranged in such a manner that when the lever was applied nothing but vertical pressure would be transmitted to the briquette. Some trouble was experienced with sand getting between the socket in the board and the piece cut out of same, and it is believed that some inaccuracies have crept into the work, owing to the irregular pressure produced by the imperfect fit of these parts; but it could not be so great as the irregular and uncertain pressure applied by the hand, even of an experienced operator. The pressure was applied by putting a constant weight on the end of the lever. A set of tests was made (Table No. 7) with varying pressures obtained by a longer lever than the one used for the main work, to see what would be the effect of the different pressures. By this table it will be seen that, although the effect of an increase of pressure is quite marked, yet slight changes, sometimes even doubling the pressure, have very little effect. It is, therefore, probable that such slight changes as might be produced by irregular friction of the working parts of the machine used, would produce but little if any effect on the strength of individual briquettes in any one set. As soon as taken from the press, the briquettes were removed from the moulds, placed on a

stone slab and covered with a wet cloth, where they remained for twenty-four hours, when they were immersed in water for the required time. The briquettes were identified by means of letters and numbers. Just before removing from the moulds, a figure was pressed into one head and a letter into the other with a rubber stamp. The letter indicated the cement used, the number being the number of the set made with that cement. The briquettes were broken with a Fairbanks machine of 1,000 pounds capacity, and the strain was applied at the rate of about 300 pounds per minute (see illustration opposite).

In order to compare the general accuracy of this work with that of other operators, the writer has constructed a table of results (Table No. 26) from three other sources, in all of which the methods recommended by the American Society of Civil Engineers were used. The first two investigators were students just from college, and could not have had any great amount of experience, especially as compared with Col. Poe. It will be seen that the results obtained by the writer are, at least, as accurate as those of Col. Poe, a circumstance which he attributes to the better methods he employed. In Table 26 the greatest difference of any one briquette from the mean of the set was used, and this difference divided by the mean strain of the set, to get the percentage of error. Where more than one set was given, the mean of all of these differences was divided by the mean of all of the strains. The greatest difference in any one set is also given, but the percentage is figured from the mean. No attempt was made to secure a uniform temperature, but in nearly all cases each series of tests was made on the same day, so that each set in each series was subjected to the same temperature.

DESCRIPTION OF SANDS.

River Sands.—This sand was taken from the bed of the Savannah River. It is of light-yellow color, quite clear, and is composed of a mixture of sharp grains, and well-rounded ones. The coarse grades seem to have a greater percentage of rounded grains than the fine ones. (See Tables Nos. 11 and 12.)

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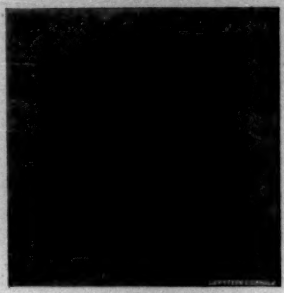
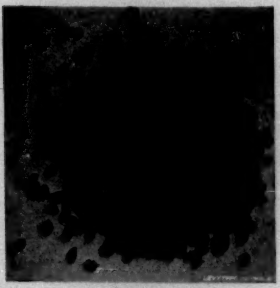
RIVER SAND.
Size, 70-80.



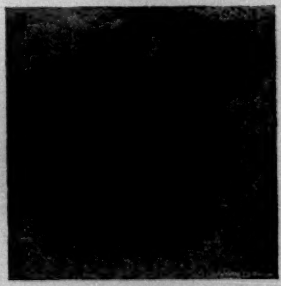
RIVER SAND.
Size, 20-30.



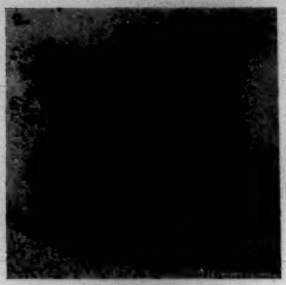
RIVER SAND.
Size, 12-16.

AUGUSTA, No. 1.
Size, 20-30.

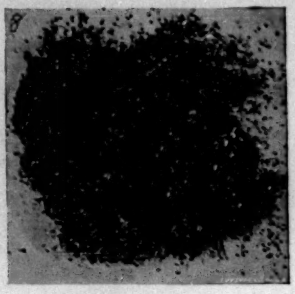
AUGUSTA, No. 1.
Size, 12-16.



COCKSPUR BEACH.
Size, 70-80.

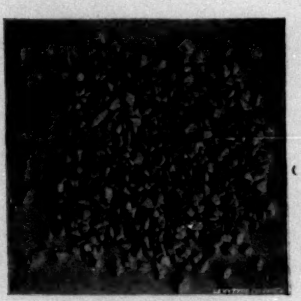


AUGUSTA, No. 2.
Size, 120-140.



AUGUSTA, No. 2.
Size, 30-40.

FLORIDA LIMESTONE.
Size, 20-30.



FLORIDA LIMESTONE.
Size, 12-16.

RED SANDSTONE.
Size, 30-40.

RED SANDSTONE.
Size, 20-30.

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Beach Sands.—The beach sands are much clearer and whiter than the river sands. But for some black particles, they would be as white as snow. They are quite sharp and apparently have a smaller percentage of rounded grains than the river sands. The sharp grains present edges and corners that appear to be worn a little smooth. The grade that passed the 140 sieve was just as sharp and free from dust or dirt as the coarser grades. (See Tables Nos. 8, 9 and 10.)

Tybee Bar.—This sand was taken from the outer bar at Tybee. It is practically identical with the beach sand, except that it contains more black particles and a little larger percentage of the very fine grades. (See Table No. 14.)

Cumberland Quicksand.—Under the microscope this sand looks about the same as beach sand, being a little whiter and clearer, and having more black grains in the lowest grade. The grading shows it to be a little coarser, but no difference was noticed as to sharpness. When wet it feels grating to the touch, as if it were glassy, and when thrown from hand to hand it makes a little noise, very much like the clucking of a hen. (See Table No. 17.)

Warsaw Quicksand.—This sand has all of the characteristics of the Cumberland quicksand, as has also the quicksand from St. John's Bar. (See Tables Nos. 16 and 18.)

Augusta, No. 1.—This sand is very similar to river sand, except that it has fewer rounded grains. It was taken from a pit in the Savannah River Valley, at Augusta. (See Table No. 13.)

Augusta, No. 2.—This was taken from the same pit as No. 1, and is practically identical with the beach sands in every particular, except as to color, being yellow instead of white. (See Table No. 15.)

Red Sandstone.—This sand was obtained by pulverising red sandstone. The grains have rounded edges and are covered with a dust of a reddish color, but are usually oblong in shape. Size 20–30 was not composed of individual grains, but was made up of smaller ones cemented together, and hence they have a very ragged surface. The size that passed 140 was mostly dust. (See Table No. 23.)

Brown Sandstone.—Was obtained in the same manner as

red sandstone, and was very similar to it. (See Table No. 22.)

Florida Rock.—Was obtained by breaking up limestone from Florida. It was quite flinty, and broke up with extremely sharp edges. It was very light, and each grain had very smooth surfaces. (See Table No. 21.)

Trap Rock.—This was made from a very black and dense variety of trap rock, which was extremely hard to break. The surfaces of each grain were very rough. (See Table No. 19.)

Granite.—This was obtained from a fine-grained, gray granite, which broke up in a similar manner to the trap rock. (See Table No. 20.)

The illustrations shown herewith comprise three grades of each sand. They have been reproduced to natural size, in all cases from a photograph of the material itself, in order to give a better idea of the comparative shape and size of grain of each sand than could be obtained from a description.

Results.—Generally speaking, the coarser the sand, the stronger the mortar made from it; but the difference between the grades below 30–40 are so slight that, as far as sizes are concerned, they might be considered in one class. There seemed to be a tendency towards an increase in strength with grades below 100–120, but so few samples of these grades were obtained that this slight increase may be put down as accidental. There is an unmistakable indication of weakness in the upper grade, 8–12. In the tables, about two cases out of three give 12–16 as stronger than 8–12; and there is but one case, where 8–12 is the highest, that cannot be accounted for by there being more water in this grade than in the next one. The shape and condition of the surface of sands, however, has much to do with the strength, as will be seen from the results obtained from the various crushed rocks. (See Tables Nos. 19 to 23, inclusive.) The Florida rock, which broke up into the sharpest sand of all, was not as good as some of the natural sands, probably owing to extremely smooth surfaces. Trap rock was not as sharp as the Florida rock, but gave much better results on

account of the surfaces of the grains being very rough. The granite was about the same as the trap rock. The comparison of the beach and river sands, with but few exceptions, has proven the latter to be the best for cement mortar by from 2 to 10 per cent. After the grade of 40–50 is reached in the river sands, there is no practical difference between them and the beach sands. These two sands were compared by taking equal parts of sand and cement, by measure, and the result was the same as when taken by weight. The first set of experiments, in which it was found that the beach sand was the best, was unquestionably wrong; and there is no way of explaining how such a result was obtained. Greater ratios than 1 to 1 were tried (see Table, No. 25), mainly to test these two sands; and in this table the difference was found to be less noticeable. Col. Poe, in his work, found differences, due to different kinds of sand, to be greatest in mortar, where the least cement was used, and, as he did more work in that line than the writer, he may be right. The ratio of 1 to 1 was chosen for this work, however, on the supposition that it was the best for the purpose intended.

The only other series in the same line as the body of this work, that the writer could find to compare with, was that of Mr. Paul Alexandre, chief engineer of roads and bridges, France, published in "Annales des Ponts et Chaussées," 1892. His results, as far as they go, are the same as those here recorded except that his upper grade proved to be the maximum. This grade contained average grains a little coarser than the writer's upper grade, but also had a greater range of sizes; besides, the next lower grade was considerably smaller than the writer's second grade. The lowest grade was about equal to the writer's 50–60 grade, and, in the light of the present results, was quite low enough.

In Table No. 4 the weights of equal volumes of various kinds and grades of sand, poured loosely into a measure, are given. From Table No. 5 it is apparent that the specific gravity of all of these various kinds and grades of sand are not materially different, and that, therefore, the difference found between the weights of equal volumes (Table No. 4)

are principally due to different percentages of voids. It is further apparent from Table No. 5 that the smaller the grade the greater the percentage of voids in loose sand, and *vice versa;* while in well-packed sand there is practically no difference in percentage of voids. These results indicate that uniformity of mortar briquettes for tests can be obtained only by either measuring the sand while well packed, or by weighing.

CONCLUSIONS.

(1) Other things being equal, coarse sands are better than fine sands for cement mortar up to the grade 12–16, or about $\frac{1}{12}$ of an inch in diameter. (2) Below the grade 40–50, or about $\frac{1}{40}$ of an inch in diameter, there is no practical difference in the value of the different sands, as far as the size is concerned. (3) The shape and condition of the surfaces of the grains of different sands has as much to do with their value for cement mortar as the size.

SAVANNAH, GA., July 1, 1895.

TABLE No. 1.—GIVING FINENESS OF CEMENTS USED.

CEMENT.	Size of Sieves.	Per Cent. of Cement Passed.	CEMENT.	Size of Sieves.	Per Cent. of Cement Passed.
Brooklyn Bridge	50	94·6	Norton	50	97·8
" "	70	89·	"	70	87·5
" "	100	69·	"	100	40·
Dyckerhoff	50	99·7	Milwaukee	50	94·3
"	70	99·	"	70	88·
"	100	89·	"	100	72·
"	120	82·	Giant	70	99·
Alsen	70	97·8	"	100	91·3
"	100	87·7	Louisville	50	98·5
"	120	93·	"	70	87·5
"	140	90·	"	100	70·
Hoffman	50	90·6			
"	70	87·5			
"	100	40·			

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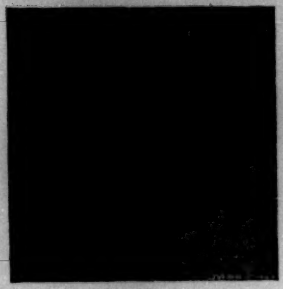
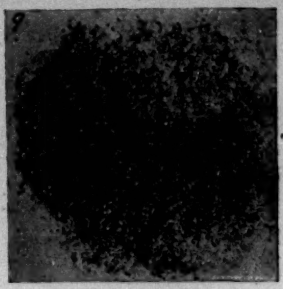
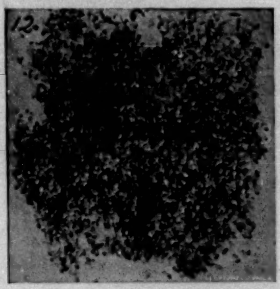


CUMBERLAND QUICKSAND.
Size, passed 140.

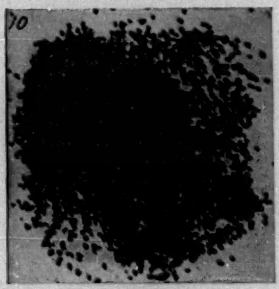


CUMBERLAND QUICKSAND.
Size, 40-50.

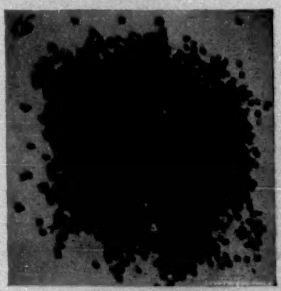


CUMBERLAND QUICKSAND.
Size, 30-40.

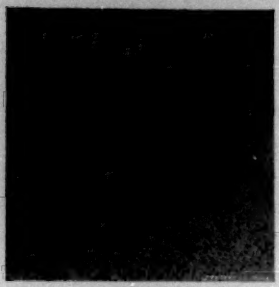
BROWN SANDSTONE.
Size, 120-140.



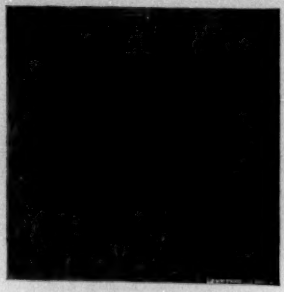
BROWN SANDSTONE.
Size, 20-30.



BROWN SANDSTONE.
Size, 16-20.

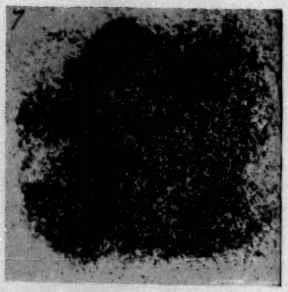


GRANITE.
Size, 80-100.

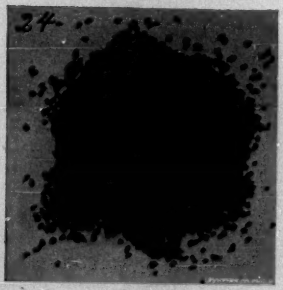


GRANITE.
Size, 20-30.

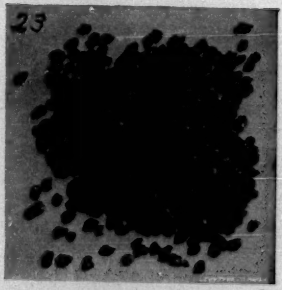
GRANITE.
Size, 12-16.



TRAP ROCK.
Size, 70-80.



TRAP ROCK.
Size, 20-30.



TRAP ROCK.
Size, 12-16.

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TABLE No. 2.—Showing Sieves Used and Grades of Sands Obtained by their Use.

No. of Sieves.	No. of Wires in One Direction.	No. of Wires in Opposite Direction.	No. of Wire.	Size of Wire.	Size of Openings.	Grade of Sands.	Mean Size of Grains.
8	8	8	23	'025	'1000	8–12	'0830
12	12	12	28	'0165	'0670	12–16	'0560
16	16	16	28	'0165	'0460	16–20	'0420
20	19	20	30	'01375	'0388	20–30	'0310
30	29	30	32	'011125	'0232	30–40	'0200
40	36	40	33	'01025	'0175	40–50	'0150
50	45	48	34	'00950	'0125	50–60	'0110
60	52	60	35	'00900	'0102	60–70	'0095
70	55	69	36	'00750	'0106 / '0070	70–80	'0078
80	79	80	38	'00575	'0069	80–100	'0064
100	95	100	40	'00450	'0060	100–120	'0057
120	120	120	45	'00290	'0054	120–140	'0050
140	140	140	46	'00240	'0047	P. 140	Below '0047

TABLE No. 3.—Giving Per Cents. of Each Grade Found in River Sand and Cockspur Beach Sand.

Grade.	Per Cent. Found.	Grade.	Per Cent. Found.	Grade	Per Cent. Found.
River Sand, No. 1.		River Sand, No. 2.		Cockspur Beach.	
		8–12	3'2		
12–16	3'4	12–16	6'0	60–70	1'7
16–20	1'6	16–20	6'0	70–80	36'7
20–30	14'0	20–30	19'7	80–100	41'7
30–40	41'5	30–40	24'5	100–120	13'3
40–50	28'0	40–50	15'0	120–140	4'1
50–60	7'0	50–60	14'4	P. 140	2'5
60–70	1'6	60–70	9'1		100'0
70–80	2'6	70–80	4'7		
P. 80	0'3	P. 80	0'4		
	100'0		103'0		

TABLE No. 4.—Giving Weights of 24 Cubic Inches of Different Kinds and Grades of Sand (Sand Poured Loosely into Cup).

Kind of Sand.	Grade.	Weight of 24 Cubic Inches in Ounces.	Kind of Sand.	Grade.	Weight of 24 Cubic Inches in Ounces.
River Sand, No. 1	8–12	20¾	Augusta, No. 2	40–50	16¾
" "	12–16	19¾	Red Sandstone	70–80	18
" "	16–20	19¾	St. John Bar, Quicks'd	All	16¾
" "	20–30	19¾	Florida Rock	8–12	16
" "	30–40	18¾	Trap "	8–12	20
" "	40–50	18¾	" "	12–16	19¾
" "	50–60	18¾	" "	P. 100	17½
" "	60–70	18¾	Granite	8–12	18½
" "	70–80	18¾	"	12–16	17¾
Augusta, No. 1	20–30	18¾			
" "	12–16	18¾			
" "	30–40	18			
" No. 2	70–80	18			
Cockspur Beach	All	18¾			
Tybee Beach, No. 2	20–30	19½			
River Sand, No. 2	30–40	18¾			

TABLE No. 5.—Showing the Voids in Different Sizes of Sands; also Specific Gravity.

1	2	3	4	5	6	7	8	9	10	11	12
Size of Sand.	Weight of Bottle.	Weight of Bottle and Dry Sand Loose.	No. 3, with Water Added.	Per Cent. of Voids in Loose Sand.	Specific Gravity Derived from 2, 3 and 4.	Weight of Glass.	Glass and Dry Sand Loose.	No. 8, After Having Been Shaken Down and More Sand Added.	No. 9. After Adding Water.	Voids from 7, 9 and 10.	Specific Gravity from 7, 9 and 10.
	oz.	*oz.*	*oz.*			*oz.*	*oz.*	*oz.*	*oz.*		
River Sand.											
8–12	8½	20½	23⅝	43·7	2·58	8¾	19¾	20½	23⅜	42·2	2·62
12–16	8½	19¾	23½	45·6	2·64	8¾	19½	20½	24	42·2	2·65
16–20	8½	19½	23¾	45·6	2·60	8¾	19⅜	20½	24	42·2	2·65
20–30	8½	19¾	23½	48·4	2·60	8¾	19½	20½	24	42·2	2·65
30–40	8½	19	23	50·0	2·62	—	—	—	—	—	—
40–50	8¼	18¾	22¾	51·5	2·61	8¾	18¾	20½	23⅜	42·2	2·62
50–60	8½	18½	22¾	51·5	2·61	8¾	19	20½	24	42·2	2·65
60–70	8¼	18¾	22¾	50·0	2·56	8¾	18⅞	20½	24⅛	43·8	2·72
70–80	8½	18½	22⅞	50·0	2·59	8¾	18⅞	20½	24	42·2	2·65
Cockspur Beach Sand.											
70–80	—	—	—	—	—	8¾	18⅛	20	23⅛	43·8	2·64
80–100	—	—	—	—	—	8¾	18⅛	20½	23⅜	42·2	2·62
100–120	—	—	—	—	—	8¾	18⅛	20½	24	42·2	2·62
120–140	—	—	—	—	—	8¾	18⅞	20¾	24⅛	42·2	2·60

Note.—Both bottle and glass contained 14 cubic inches, and, when level full, each would hold 8 ounces of water (artesian).

TABLE No. 6.—Variation of Water.

Cement.	Kind of Sand.	Size of Sand.	Date Mixed.	Per Cent. Water.	7 Days.			56 Days.		
					No. of Tests.	Mean Strain.	Greatest Dif. from Mean.	No. of Tests.	Mean Strain.	Greatest Dif. from Mean.
Brooklyn Bridge.	Tybee Beach	80–100	Apr. 6	16·4	4	24	3	4	78	12
" " "	" "	80–100	" 6	13·7	4	24	3	4	70	4
" " "	" " No. 2	20–30	" 6	11·3	4	35	6	4	80	8
" " "	" " "	20–30	" 6	13·7	4	42	3	4	93	14
" " "	" " "	20–30	" 6	14·2	4	42	2	4	107	7
" " "	" " "	20–30	" 6	14·6	4	48	3	4	119	14
" " "	" " "	20–30	" 6	16·4	4	41	2	4	131	11
" " "	Cumberland Quicks'd	70–80	" 6	14·9	3	37	1	4	91	10
" " "	" "	70–80	" 6	16·4	4	31	2	4	107	5
" " "	" "	70–80	" 6	18·0	4	28	3	4	117	10

TABLE No. 7.—VARIATION OF PRESSURE.

CEMENT.	Kind of Sand.	Size of Sand.	Pressure Per Square Inch.	Per Cent. Water.	Date Mixed.	7 DAYS.			56 DAYS.		
						No. of Tests.	Mean Strain	Greatest Dif. from Mean.	No. of Tests.	Mean Strain.	Greatest Dif. from Mean.
Dyckerhoff	Tybee Beach	50–100	H. T.	12·7	Mar. 26	4	161	18	3	228	13
"	" "	80–100	675	12·7	" 26	4	129	10	4	152	6
"	" "	All	H. T.	12·7	" 26	4	172	17	4	186	40
"	" "	"	675	12·7	" 26	4	148	8	4	202	29
"	River Sand, C. R.	30–40	H. T.	11·9	" 26	3	239	20	4	247	38
"	" "	12–16	"	11·2	" 26	3	233	7	4	236	14
"	" "	12–16	675	12·5	" 26	2	307	8	2	298	18
"	Cockspur Beach	All	1,400	11·9	Apr. 1	4	142	15	3	213	9
"	" "	"	200	11·9	" 1	4	98	6	4	176	22
"	River Sand, C. R.	20–30	1,400	11·2	" 1	3	198	20	4	286	11
"	" "	20–30	200	11·9	" 1	4	146	18	4	221	5
Hoffman	Cockspur Beach	All	1,400	16·4	Mar. 30	3	41	4	4	128	18
"	" "	"	H. T.	16·4	" 29	4	37	3	4	133	15
"	" "	"	770	16·4	" 29	4	36	3	4	115	19
"	" "	"	1,400	16·4	Apr. 1	3	35	6	4	122	11
"	" "	"	770	16·4	" 1	4	34	2	3	135	17
"	" "	"	495	16·4	" 1	4	28	2	3	90	11
"	" "	"	200	16·4	" 1	4	26	3	4	94	5
"	River Sand, C. R.	20–30	1,400	14·2	Mar. 30	3	57	2	4	146	17
"	" "	20–30	770	14·9	" 29	3	48	7	4	130	7
"	" "	20–30	H. T.	14·9	" 29	4	45	4	4	106	17
"	" "	20–30	1,400	14·9	Apr. 1	4	56	3	3	196	7
"	" "	20–30	770	14·9	" 1	4	54	4	3	125	14
"	" "	20–30	495	14·9	" 1	4	47	4	3	114	8
"	" "	20–30	200	14·9	" 1	4	33	5	4	100	11

NOTE.—H. T. means hand-tamped by the method previously described.

TABLE No. 8.—COCKSPUR BEACH.

CEMENT.	Size of Sieves.	Date Mixed.	Per Cent. Water.	7 DAYS.			56 DAYS.		
				No. of Tests	Mean Strain.	Greatest Dif. from Mean.	No. of Tests	Mean Strain.	Greatest Dif. from Mean.
Dyckerhoff	All	Mar. 12	13'5	3	119	2	5	197	18
"	60–70	" 14	14'3	—	—	—	2	218	2
"	70–80	" 14	14'2	4	126	13	4	201	4
"	80–100	" 14	14'2	4	134	3	4	209	10
"	100–120	" 14	14'2	4	136	21	5	201	11
"	120–140	" 14	14'3	3	139	10	4	236	38
"	Passed 140	" 14	13'5	1	152	—	2	183	6
Giant	70–80	" 14	14'2	4	124	12	4	215	8
"	All	" 13	14'0	4	134	3	4	229	13
"	Held by 100	" 15	14'2	4	141	16	4	212	9
Alsen	All	" 13	15'5	3	186	9	4	262	15
Louisville	"	" 13	17'1	4	34	4	4	137	19
Norton	"	" 13	16'0	4	28	2	4	97	7
Brooklyn Bridge	"	" 13	15'0	4	27	1	4	89	7
Hoffman	"	" 13	16'0	4	26	2	4	100	8
Milwaukee	80–100	" 14	19'4	4	34	2	4	90	14
"	All	" 13	17'2	—	—	—	4	80	9
"	Held by 100	" 15	20'0	4	32	2	4	91	4
Brooklyn Bridge	100–120	" 14	16'0	5	21	1	4	91	10
" "	80–100	" 14	16'4	4	23	2	4	88	6
" "	Held by 100	" 15	16'4	4	24	0	4	99	2
Hoffman	70–80	" 14	16'4	4	23	2	4	100	9
"	Held by 100	" 15	16'4	4	25	1	4	91	8
Louisville	70–80	" 14	19'4	4	70	6	4	135	7
"	Held by 100	" 15	19'4	4	70	5	5	132	5
Norton	" 100	" 15	18'4	4	27	5	4	96	6
"	70–80	" 14	16'4	4	23	3	4	107	3
"	80–100	" 14	16'4	4	23	2	4	94	12
"	100–120	" 14	16'8	4	25	2	5	105	17
"	120–140	" 14	17'3	4	30	2	3	97	7
"	Passed 140	" 14	16'0	—	—	—	2	100	11

TABLE No. 9.—TYBEE BEACH, No. 1.

CEMENT.	Size of Sieves.	Date Mixed.	Per Cent. Water.	7 DAYS.			56 DAYS.		
				No. of Tests	Mean Strain.	Greatest Dif. from Mean.	No. of Tests	Mean Strain.	Greatest Dif. from Mean.
Dyckerhoff	50–60	Mar. 26	11'7	—	—	—	2	182	14
"	60–70	" 26	13'1	—	—	—	2	181	11
"	70–80	" 26	12'6	4	95	5	4	159	15
"	80–100	" 26	12'6	4	107	13	4	183	14
"	100–120	" 26	13'5	—	—	—	3	162	5
"	All	" 26	12'0	4	110	5	4	178	10
Giant	60–70	" 23	13'5	1	112	—	2	201	2
"	70–80	" 23	13'7	2	114	1	3	176	39
"	80–100	" 23	13'7	2	127	5	3	202	9
"	100–120	" 23	13'7	2	125	8	3	191	5
"	120–140	" 23	15'0	2	129	4	3	203	12
"	Passed 140	" 23	15'3	2	117	2	3	196	23
"	All	" 23	14'2	4	130	8	4	189	8
Brooklyn Bridge	70–80	" 23	16'4	4	84	3	4	89	4
" "	80–100	" 23	16'4	3	92	9	4	84	11
" "	100–120	" 23	16'4	5	20	3	4	78	8
" "	120–140	" 23	14'3	—	—	—	1	97	—
" "	All	" 23	16'4	4	92	1	4	90	3
Louisville	70–80	" 21	21'0	4	61	6	4	129	13
Hoffman	70–80	" 29	16'4	4	28	2	4	104	8
"	80–100	" 29	16'4	4	28	3	4	98	8
"	100–120	" 29	15'2	2	34	2	2	84	3
"	120–140	" 29	16'2	—	—	—	3	90	5
"	Passed 140	" 29	22'4	—	—	—	2	110	3
Dyckerhoff	70–80	Apr. 4	12'7	4	128	3	4	183	30
"	70–80	" 6	12 7	3	109	20	4	164	7

TABLE No. 10.—Tybee Beach, No. 2.

Cement	Size of Sieves.	Date Mixed.	Per Cent. Water.	7 Days.			56 Days.		
				No. of Tests	Mean Strain.	Greatest Dif. from Mean.	No. of Tests	Mean Strain.	Greatest Dif. from Mean.
Brooklyn Bridge	16–20	Apr. 4	14·3	—	—	—	2	54	20
" "	20–30	" 4	15·0	4	39	6	4	100	14
" "	30–40	" 4	15·0	4	39	2	4	100	4
" "	40–50	" 4	14·3	—	—	—	2	76	1
" "	50–60	" 4	15·3	—	—	—	2	94	3
" "	60–70	" 4	16·7	—	—	—	1	86	—
" "	70–80	" 4	15·7	4	28	4	4	79	5
" "	80–100	" 4	15·7	4	20	1	4	72	6
" "	100–120	" 4	16·0	2	24	1	3	80	9
" "	120–140	" 4	13·2	—	—	—	1	67	—

TABLE No. 11.—River Sand, No. 1.

Cement.	Size of Sieves.	Date Mixed.	Per Cent Water.	7 Days.			56 Days.		
				No. of Tests	Mean Strain.	Greatest Dif. from Mean.	No. of Tests	Mean Strain.	Greatest Dif. from Mean.
Dyckerhoff	8–12	Mar. 14	12·5	—	—	—	1	332	—
"	12–16	" 15	9·7	2	189	4	2	232	3
"	16–20	" 15	10·0	2	173	2	2	195	10
"	20–30	" 15	11·5	2	158	1	3	212	1
"	30–40	" 16	11·2	4	150	9	4	177	20
"	40–50	" 16	12·0	4	147	13	4	187	10
"	50–60	" 15	12·0	4	137	13	4	190	8
"	60–70	" 15	11·1	2	144	3	2	187	3
"	70–80	" 15	11·1	4	119	9	—	—	—
"	All	" 12	14·0	4	162	28	5	218	17
Giant	20–30	" 16	13·3	2	191	8	3	267	16
"	30–40	" 16	14·3	4	145	9	4	190	12
"	40–50	" 16	14·5	4	138	15	4	194	12
"	All	" 13	13·3	3	158	8	4	245	36
Alsen	"	" 13	14·4	3	254	22	4	269	32
Louisville	"	" 13	17·3	4	62	7	4	128	12
"	"	" 16	20·0	2	82	1	3	144	34
"	30–40	" 16	17·2	—	—	—	2	123	19
"	20–30	" 15	20·7	2	42	—	4	129	1
"	30–40	" 16	16·0	3	37	6	4	100	8
"	40–50	" 16	22·0	2	34	2	2	113	5
"	All	" 13	16·4	3	37	5	4	104	9
Norton	20–30	" 15	15·0	2	35	2	3	105	12
"	30–40	" 16	14·2	4	31	4	4	91	11
"	40–50	" 16	14·2	4	34	1	4	95	16
"	50–60	" 15	15·0	4	33	—	4	103	8
"	All	" 13	16·4	4	36	3	4	114	10
Brooklyn Bridge	20–30	" 15	15·2	2	35	1	3	107	11
" "	30–40	" 16	14·2	4	32	3	4	86	11
" "	40–50	" 16	14·2	4	31	2	4	82	5
" "	50–60	" 15	16·0	—	—	—	2	85	3
" "	All	" 13	14·1	4	33	1	2	101	7
Hoffman	20–30	" 16	14·1	2	35	1	3	92	5
"	30–40	" 16	14·2	4	32	5	4	83	9
"	40–50	" 15	14·2	4	34	1	4	15	8
"	All	" 13	16·0	4	25	4	2	110	19

TABLE No. 12.—River Sand, No. 2.

Cement.	Size of Sieves.	Date Mixed.	Per Cent. Water.	7 Days.			56 Days.		
				No. of Tests	Mean Strain.	Greatest Dif. from Mean.	No. of Tests	Mean Strain.	Greatest Dif. from Mean.
Dyckerhoff	12–16	Mar. 25	11·2	3	157	2	4	198	10
"	16–20	" 25	11·6	3	157	12	4	224	29
"	20–30	" 25	11·9	4	153	8	4	200	6
"	30–40	" 25	11·9	4	140	18	4	161	17
"	30–40	" 19	11·9	4	154	9	4	183	31
"	40–50	" 25	11·9	4	124	2	4	166	14
Giant	8–12	" 22	12·8	3	108	20	3	153	21
"	12–16	" 22	11·9	3	135	13	4	183	14
"	16–20	" 22	11·9	3	139	13	4	188	18
"	20–30	" 22	11·9	3	149	13	4	189	18
"	30–40	" 22	12·6	4	139	4	4	175	18
"	30–40	" 19	11·9	3	144	9	4	189	9
"	40–50	" 22	13·4	4	140	7	4	178	18
"	50–0	" 22	14·3	2	131	4	2	209	10
Louisville	8–12	" 21	19·8	4	63	12	4	99	20
"	12–16	" 21	19·8	4	88	4	4	140	19
"	16–20	" 21	17·9	4	66	8	4	106	14
"	20–30	" 21	18·7	4	66	1	4	123	20
"	30–40	" 21	19·8	4	76	3	4	130	18
"	40–50	" 21	19·8	4	63	4	4	111	6
"	50–70	" 21	20·9	4	61	7	4	106	18
"	70–70	" 21	18·5	1	52	—	2	101	14
Hoffman	16–20	" 29	14·5	3	41	3	3	107	7
"	20–30	" 29	14·2	4	42	6	3	105	12
"	30–40	" 29	14·2	4	37	2	4	94	3
Norton	16–20	" 28	14·2	4	39	5	4	111	8
"	20–30	" 28	14·2	4	38	2	4	98	5
"	30–40	" 28	14·9	4	35	2	4	100	9
"	40–50	" 28	15·7	4	3	2	4	88	2
Brooklyn Bridge	12–16	" 23	13·4	4	32	3	4	98	11
" "	16–20	" 23	14·2	4	31	4	4	91	3
" "	20–30	" 23	14·2	4	35	2	4	102	13
" "	30–0	" 23	15·0	4	34	2	4	92	6
" "	30–40	" 19	14·2	3	31	3	4	92	4
" "	40–50	" 23	15·0	4	26	1	4	81	10

TABLE No. 13.—Augusta, No. 1.

Cement.	Size of Sieves.	Date Mixed.	Per Cent. Water.	7 Days.			56 Days.		
				No. of Tests	Mean Strain.	Greatest Dif. from Mean.	No. of Tests	Mean Strain.	Greatest Dif. from Mean.
Dyckerhoff	8–12	Apr. 11	11·8	2	302	7	3	231	20
"	12–16	" 11	11·6	3	257	17	4	289	24
"	16–20	" 11	11·6	3	240	9	4	273	24
"	20–30	" 11	12·3	3	242	11	4	278	22
"	30–40	" 11	12·3	3	204	11	4	259	23
"	40–50	" 11	13·1	—	—	—	4	247	21
"	Passed 140	" 11	14·0	—	—	—	1	213	—
Norton	8–12	" 9	16·3	—	—	—	2	142	1
"	12–16	" 9	14·2	4	42	6	4	101	6
"	16–20	" 9	14·2	4	47	4	4	115	14
"	20–30	" 9	14·2	4	47	2	4	108	6
"	30–40	" 9	15·0	4	44	3	4	123	10
"	40–50	" 9	16·3	—	—	—	3	124	5
Brooklyn Bridge	12–16	" 10	14·2	—	—	—	8	97	9
" "	16–20	" 10	15·0	—	—	—	8	116	16
" "	20–30	" 10	15·0	—	—	—	8	110	8
" "	30–40	" 10	15·7	—	—	—	8	110	9
Hoffman	12–16	" 9	14·1	—	—	—	4	209	9
"	16–0	" 9	15·9	2	41	1	4	124	7
"	20–30	" 9	15·0	4	35	5	4	92	6
"	30–40	" 9	16·7	4	37	4	4	103	1

TABLE No. 14.—TYBEE BAR.

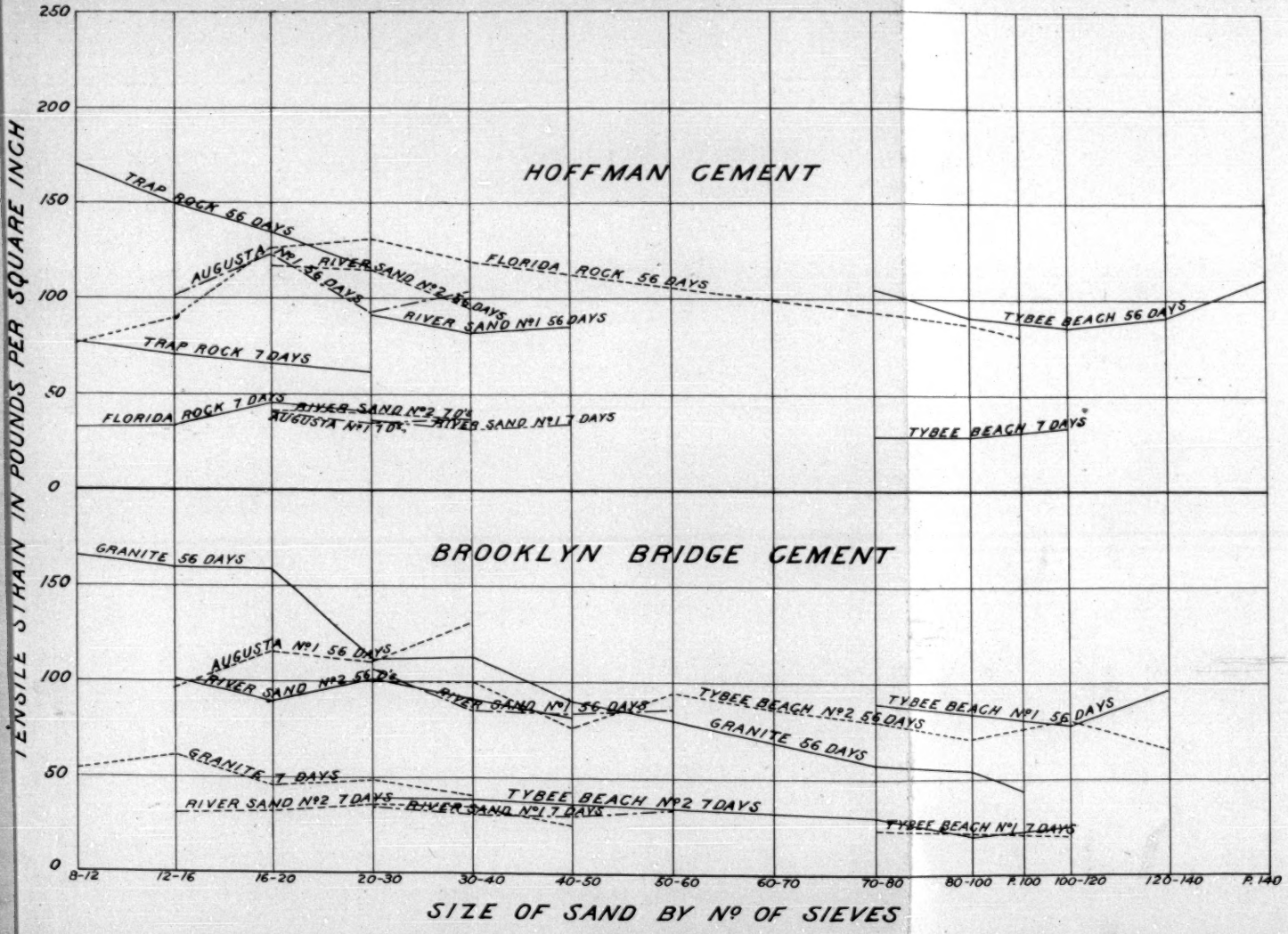
Cement.	Size of Sieves.	Date Mixed.	Per Cent. Water.	7 Days.			56 Days.		
				No. of Tests	Mean Strain.	Greatest Dif. from Mean.	No. of Tests	Strength.	Difference.
Dyckerhoff	All	Mar. 19	14·2	4	144	12	4	204	15
"	70–80	" 19	14·2	4	144	3	4	221	13
Giant	All	" 19	13·6	2	126	4	2	251	5
Louisville	80–100	" 21	20·1	4	60	13	5	128	20
"	100–120	" 21	20·0	2	62	6	3	142	2
Norton	All	" 19	16·4	4	30	3	4	103	13
"	70–80	" 19	16·3	2	28	1	3	126	15
"	80–100	" 28	16·4	4	29	3	4	106	5
"	100–120	" 28	14·3	2	31	3	3	89	4
"	120–140	" 28	13·5	1	35	—	2	83	—
"	Passed 140	" 28	—	—	—	—	2	99	3
"	½ (80–100) / ½ (20–30 River sand)	" 28	16·4	3	34	4	4	112	9
Brooklyn Bridge	All	" 19	16·4	4	28	2	4	119	15

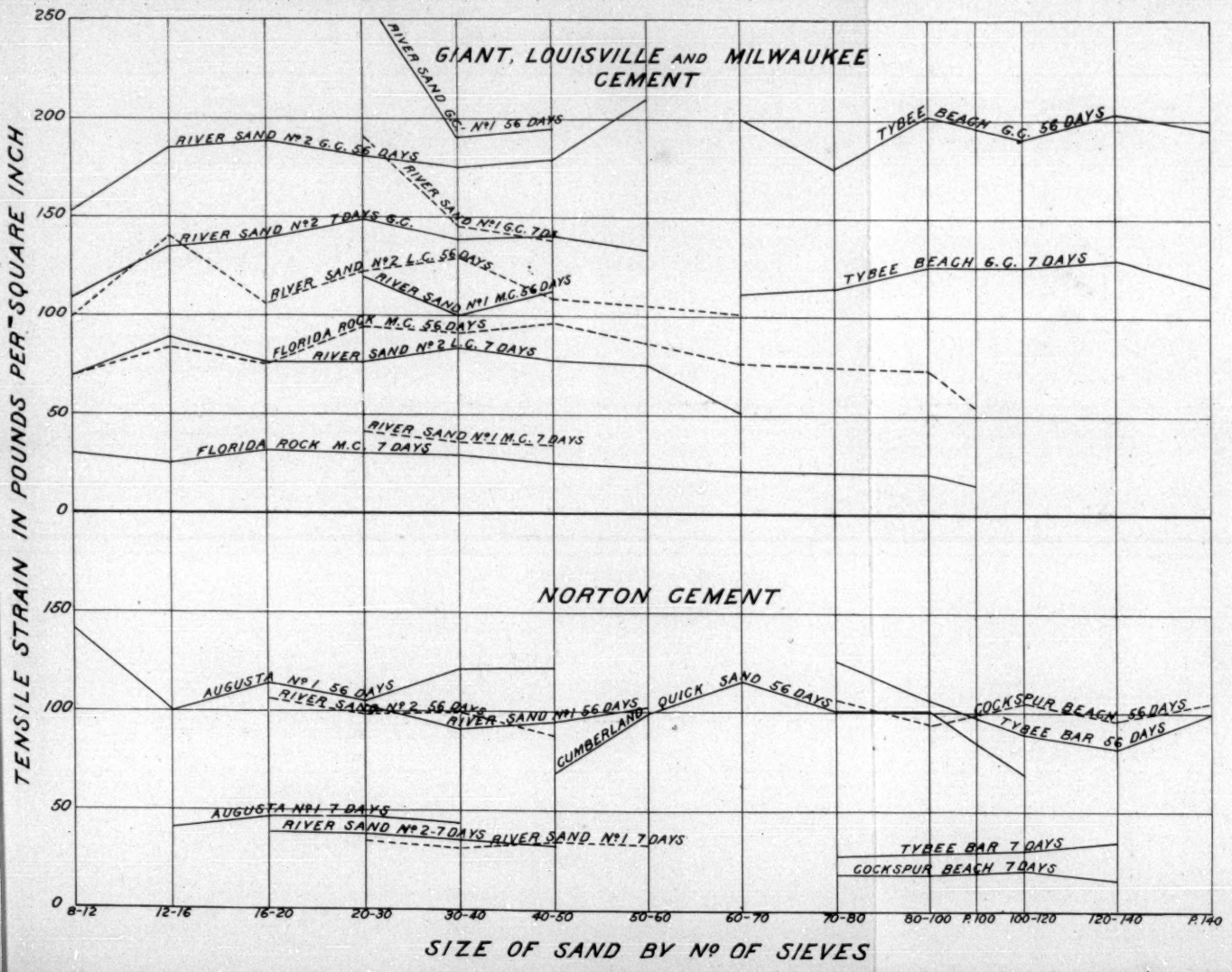
TABLE No. 15.—AUGUSTA, No. 2.

Cement.	Size of Sieves.	Date Mixed.	Per Cent. Water	7 Days.			56 Days.		
				No. of Tests	Mean Strain.	Greatest Dif from Mean.	No. of Tests	Mean Strain.	Greatest Dif. from Mean.
Dyckerhoff	30–40	Apr. 11	13·3	2	151	2	3	198	10
"	40–50	" 11	12·7	4	148	7	4	192	12
"	50–60	" 11	12·7	4	154	11	4	197	31
"	60–70	" 11	12·7	5	145	13	4	209	10
"	70–80	" 11	13·1	4	142	9	4	203	35
"	80–100	" 11	12·9	—	—	—	4	211	15
"	100–120	" 11	10·0	—	—	—	1	210	—
"	Passed 140	" 11	12·5	—	—	—	1	206	—
Brooklyn Bridge	50–60	" 10	16·4	—	—	—	8	97	18
" "	70–80	" 10	16·4	—	—	—	8	92	10

TABLE No. 16.—WARSAW QUICKSAND.

Cement.	Size of Sieves.	Date Mixed.	Per Cent. Water.	7 Days.			56 Days.		
				No. of Tests	Mean Strain.	Greatest Dif. from Mean.	No. of Tests	Mean Strain.	Greatest Dif. from Mean.
Dyckerhoff	60–70	Apr. 4	11·0	—	—	—	1	228	—
"	70–80	" 4	12·7	4	157	10	4	194	27
"	80–100	" 4	11·6	2	150	7	3	183	20


HOFFMAN CEMENT
TRAP ROCK 56 DAYS
AUGUSTA No1 56 DAYS
RIVER SAND No2 56 DAYS
FLORIDA ROCK 56 DAYS
RIVER SAND No1 56 DAYS
TYBEE BEACH 56 DAYS
TRAP ROCK 7 DAYS
FLORIDA ROCK 7 DAYS
RIVER SAND No2 7 DAYS
AUGUSTA No1 7 DAYS
RIVER SAND No1 7 DAYS
TYBEE BEACH 7 DAYS
BROOKLYN BRIDGE CEMENT
GRANITE 56 DAYS
AUGUSTA No1 56 DAYS
RIVER SAND No2 56 DAYS
RIVER SAND No1 56 DAYS
TYBEE BEACH No2 56 DAYS
TYBEE BEACH No1 56 DAYS
GRANITE 56 DAYS
GRANITE 7 DAYS
RIVER SAND No2 7 DAYS
RIVER SAND No1 7 DAYS
TYBEE BEACH No2 7 DAYS
TYBEE BEACH No1 7 DAYS
TENSILE STRAIN IN POUNDS PER SQUARE INCH
250
200
150
100
50
0
150
100
50
0
8-12
12-16
16-20
20-30
30-40
40-50
50-60
60-70
70-80
80-100
P.100
100-120
120-140
P.140
SIZE OF SAND BY No OF SIEVES


GIANT, LOUISVILLE AND MILWAUKEE CEMENT
RIVER SAND G.C. No 1 56 DAYS
RIVER SAND No 2 G.C. 56 DAYS
RIVER SAND No 1 G.C. 7 DAYS
RIVER SAND No 2 7 DAYS G.C.
RIVER SAND No 2 L.C. 56 DAYS
RIVER SAND No 1 M.C. 56 DAYS
FLORIDA ROCK M.C. 56 DAYS
RIVER SAND No 2 L.C. 7 DAYS
RIVER SAND No 1 M.C. 7 DAYS
FLORIDA ROCK M.C. 7 DAYS
TYBEE BEACH G.C. 56 DAYS
TYBEE BEACH G.C. 7 DAYS
NORTON CEMENT
AUGUSTA No 1 56 DAYS
RIVER SAND No 2 56 DAYS
RIVER SAND No 1 56 DAYS
CUMBERLAND QUICK SAND 56 DAYS
COCKSPUR BEACH 56 DAYS
TYBEE BAR 56 DAYS
AUGUSTA No 1 7 DAYS
RIVER SAND No 2 7 DAYS
RIVER SAND No 1 7 DAYS
TYBEE BAR 7 DAYS
COCKSPUR BEACH 7 DAYS
TENSILE STRAIN IN POUNDS PER SQUARE INCH
250
200
150
100
50
0
150
100
50
0
8-12
12-16
16-20
20-30
30-40
40-50
50-60
60-70
70-80
80-100
P.100
100-120
120-140
P.140
SIZE OF SAND BY No OF SIEVES

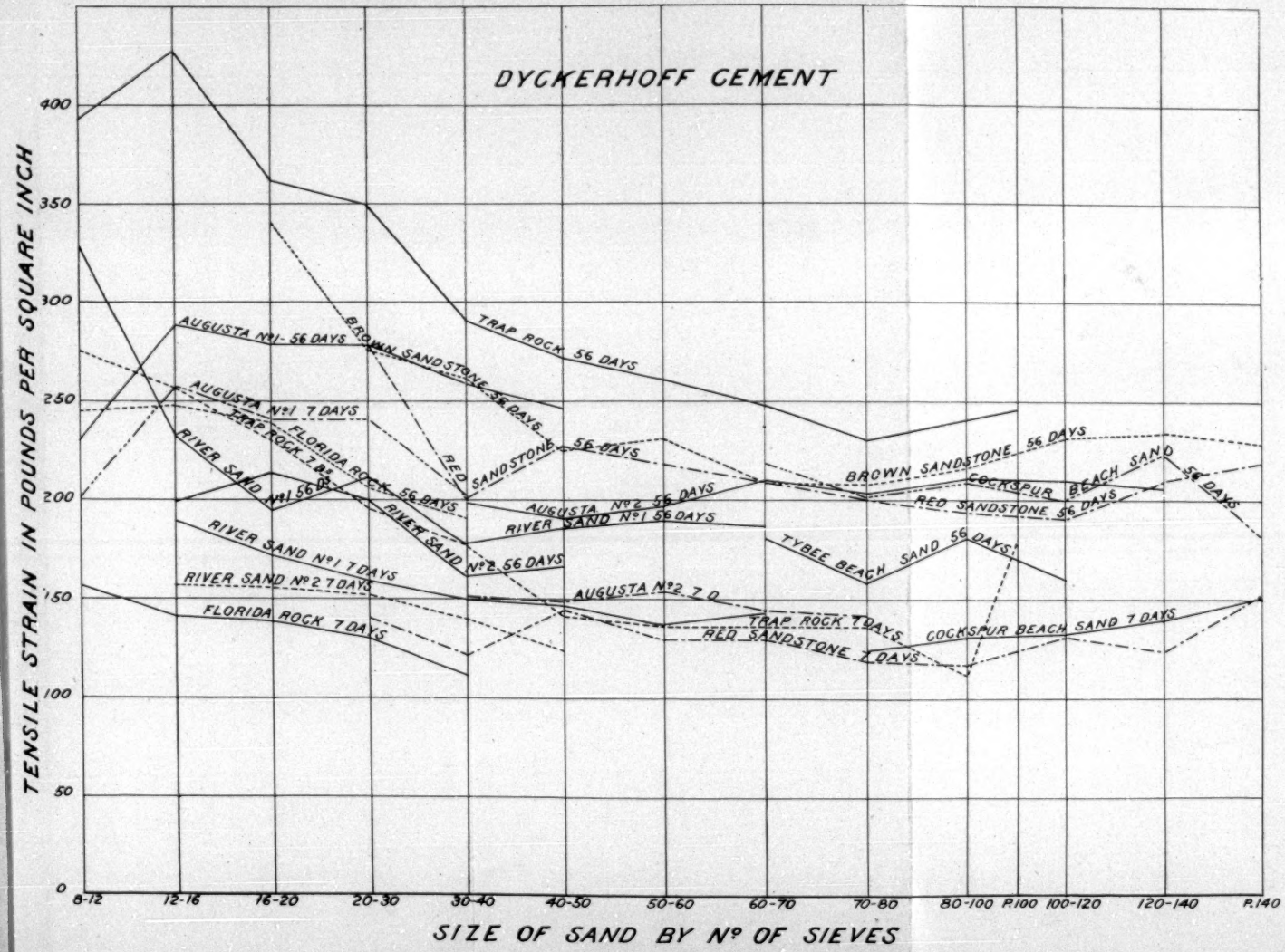

DYCKERHOFF CEMENT
TENSILE STRAIN IN POUNDS PER SQUARE INCH
0
50
100
150
200
250
300
350
400
AUGUSTA No1- 56 DAYS
BROWN SANDSTONE 56 DAYS
TRAP ROCK 56 DAYS
AUGUSTA No1 7 DAYS
TRAP ROCK 7 DAYS
FLORIDA ROCK 56 DAYS
RIVER SAND No1 56 DAYS
RED SANDSTONE 56 DAYS
AUGUSTA No2 56 DAYS
RIVER SAND No1 56 DAYS
RIVER SAND No2 56 DAYS
BROWN SANDSTONE 56 DAYS
COCKSPUR BEACH SAND 56 DAYS
RED SANDSTONE 56 DAYS
TYBEE BEACH SAND 56 DAYS
RIVER SAND No1 7 DAYS
RIVER SAND No2 7 DAYS
AUGUSTA No2 7 D
FLORIDA ROCK 7 DAYS
TRAP ROCK 7 DAYS
COCKSPUR BEACH SAND 7 DAYS
RED SANDSTONE 7 DAYS
8-12
12-16
16-20
20-30
30-40
40-50
50-60
60-70
70-80
80-100
P.100
100-120
120-140
P.140
SIZE OF SAND BY No OF SIEVES

TABLE No. 17.—CUMBERLAND QUICKSAND.

CEMENT.	Size of Sieves.	Date Mixed.	Per Cent. Water.	7 DAYS.			56 DAYS.		
				No. of Tests	Mean Strain.	Greatest Dif. from Mean.	No. of Tests	Mean Strain.	Greatest Dif. from Mean.
Dyckerhoff	70–80	Apr. 6	12·7	4	150	13	4	174	28
"	80–100	" 6	12·1	—	—	—	3	179	11
Norton	40–50	" 6	25·0	—	—	—	1	69	—
"	50–60	" 6	19·2	—	—	—	2	101	13
"	60–70	" 6	17·1	—	—	—	5	116	12
"	70–80	" 6	15·7	4	36	4	4	101	6
"	80–100	" 6	15·7	4	40	3	4	101	7
"	100–120	" 6	13·3	—	—	—	1	70	—

TABLE No. 18.—ST. JOHN'S BAR.

CEMENT.	Size of Sieves.	Date Mixed.	Per Cent. Water.	7 DAYS.			56 DAYS.		
				No. of Tests	Mean Strain.	Greatest Dif. from Mean.	No. of Tests	Mean Strain.	Greatest Dif. from Mean.
Dyckerhoff	7–80	Apr. 25	13·2	—	—	—	1	131	—
"	80–100	" 25	9·1	—	—	—	4	190	11

TABLE No. 19.—TRAP ROCK.

CEMENT.	Size of Sieves.	Date Mixed.	Per Cent. Water.	7 DAYS.			56 DAYS.		
				No. of Tests	Mean Strain.	Greatest Dif. from Mean.	No. of Tests	Mean Strain.	Greatest Dif. from Mean.
Dyckerhoff	8–12	Apr. 3	11·9	2	276	4	4	393	21
"	12–16	" 3	11·9	2	256	1	4	418	23
"	16–20	" 3	11·9	3	232	5	4	363	24
"	20–30	" 3	11·9	3	196	8	4	349	13
"	30–40	" 3	12·7	4	178	12	4	290	25
"	40–50	" 3	11·5	2	143	5	2	273	20
"	50–60	" 3	12·5	2	136	2	2	262	8
"	60–70	" 3	12·5	—	—	—	2	248	2
"	70–80	" 3	13·3	3	136	8	2	231	19
"	80–100	" 3	11·1	1	111	—	2	241	7
"	Passed 100	" 3	16·4	4	177	5	4	246	27
Hoffman	8–12	" 4	14·4	3	77	9	5	170	18
"	12–16	" 4	14·8	4	70	6	4	151	15
"	16–20	" 4	13·3	—	—	—	1	135	—
"	20–30	" 4	17·5	3	60	2	3	114	30
"	Passed 100	" 4	21·0	4	22	2	4	60	9
Brooklyn Bridge	8–12	" 4	14·2	4	62	8	4	156	9
" "	12–16	" 4	14·2	4	60	6	4	166	28

TABLE No. 20.—GRANITE.

CEMENT.	Size of Sieves.	Date Mixed.	Per Cent. Water.	7 DAYS.			56 DAYS.		
				No. of Tests	Mean Strain.	Greatest Dif. from Mean.	No. of Tests	Strength.	Difference.
Dyckerhoff	8–12	April 13	11·9	3	223	27	3	340	60
Brooklyn Bridge	8–12	" 13	14·0	4	54	4	3	167	5
" "	12–16	" 13	14·7	3	63	4	4	160	22
" "	16–20	" 13	15·4	3	46	1	4	158	17
" "	20–30	" 13	15·3	4	48	3	4	121	7
" "	30–40	" 13	17·3	3	41	3	4	124	7
" "	40–50	" 13	15·4	—	—	—	3	88	2
" "	50–60	" 13	15·1	—	—	—	3	80	10
" "	60–70	" 13	15·7	—	—	—	1	70	—
" "	70–80	" 13	18·6	—	—	—	5	57	12
" "	80–100	" 13	16·0	—	—	—	1	54	—
" "	Passed 100	" 13	29·4	—	—	—	4	45	6

TABLE No. 21.—FLORIDA LIMESTONE.

CEMENT.	Size of Sieves.	Date Mixed.	Per Cent. Water.	7 DAYS.			56 DAYS.		
				No. of Tests	Mean Strain.	Greatest Dif. from Mean.	No. of Tests	Mean Strain	Greatest Dif. from Mean.
Dyckerhoff	8–12	Mar. 27	12·5	3	157	12	4	246	22
"	12–16	" 27	11·6	4	141	6	4	248	7
"	16–20	" 27	12·5	4	139	17	4	240	41
"	20–30	" 27	13·5	4	135	11	4	207	19
"	30–40	" 27	13·9	2	113	3	2	191	5
"	Passed 100	" 27	13·7	2	116	2	2	206	6
Milwaukee	8–12	" 27	16·4	4	30	4	4	69	7
"	12–16	" 27	16·7	4	26	2	4	85	13
"	16–20	" 27	18·4	4	32	5	4	75	7
"	20–30	" 27	19·2	4	30	3	4	95	7
"	30–40	" 27	19·9	4	29	4	4	91	6
"	40–50	" 27	22·5	3	26	2	4	96	11
"	50–70	" 27	22·5	3	22	3	4	76	5
"	70–100	" 27	22·5	3	20	2	4	73	10
"	Passed 100	" 27	29·3	3	16	2	4	55	11
Hoffman	8–12	" 28	14·3	3	33	1	4	77	18
"	12–16	" 28	14·8	4	34	5	4	89	13
"	16–20	" 28	14·8	2	46	4	3	126	15
"	20–30	" 28	16·0	3	40	4	4	131	17
"	30–40	" 28	17·4	—	—	—	3	119	11
"	70–100	" 28	20·0	—	—	—	2	87	6
"	Passed 100	" 28	23·3	2	17	0	2	82	11
Brooklyn Bridge	8–12	Apr. 12	15·7	4	49	13	4	135	13

TABLE No. 22.—BROWN SANDSTONE.

Cement.	Size of Sieves.	Date Mixed.	Per Cent. Water.	7 Days.			56 Days.		
				No. of Tests	Mean Strain.	Greatest Dif. from Mean.	No. of Tests	Mean Strain.	Greatest Dif. from Mean.
Dyckerhoff	16–20	Apr. 5	13·8	—	—	—	1	341	—
"	20–30	" 5	12·3	4	170	26	4	275	24
"	30–40	" 5	12·7	4	168	21	4	261	24
"	40–50	" 5	12·0	3	157	16	4	295	27
"	50–60	" 5	12·0	—	—	—	5	231	14
"	60–70	" 5	11·1	—	—	—	2	208	4
"	70–80	" 5	12·8	3	147	—	3	207	13
"	80–100	" 5	12·9	—	—	—	4	216	21
"	100–120	" 5	13·2	—	—	—	1	232	—
"	120–140	" 5	13·3	—	—	—	1	234	—
"	Passed 140	" 5	18·5	4	155	17	4	289	23

TABLE No. 23.—RED SANDSTONE.

Cement.	Size of Sieves.	Date Mixed.	Per Cent. Water.	7 Days.			56 Days.		
				No. of Tests	Mean Strain.	Greatest Dif. from Mean.	No. of Tests	Mean Strain.	Greatest Dif. from Mean.
Dyckerhoff	20–30	Mar. 29	13·0	3	142	9	3	279	6
"	30–40	" 29	12·4	3	121	9	3	202	19
"	40–50	" 29	12·3	2	145	7	3	276	17
"	50–60	" 29	11·9	3	130	19	4	218	26
"	60–70	" 29	11·8	3	130	7	3	208	23
"	70–80	" 29	12·5	4	120	14	4	202	25
"	80–100	" 29	13·3	3	117	21	4	194	19
"	100–120	" 29	14·0	3	131	8	4	191	14
"	120–140	" 29	16·1	2	124	2	1	211	—
"	Passed 140	" 29	15·8	2	151	4	4	218	12

TABLE No. 24.—EQUAL PARTS SAND AND CEMENT, BY MEASURE, WATER COMPUTED BY WEIGHT, AS BEFORE.

Cement.	Kind of Sand.	Size of Sand.	Date Mixed.	Per Cent. Water.	7 Days.			56 Days.		
					No. of Tests.	Mean Strain.	Greatest Dif. from Mean.	No. of Tests.	Mean Strain.	Greatest Dif. from Mean.
Brooklyn Bridge	Florida Lime	8–12	Apr. 12	15·2	4	39	4	3	124	11
" "	Trap Rock	8–12	" 12	13·5	3	57	4	4	195	11
" "	Cockspur Beach	All	" 12	15·4	4	16	1	4	53	6
" "	Tybee Beach, No. 2	20–30	" 12	13·9	4	28	3	4	83	9
Dyckerhoff	Cockspur Beach	All	" 25	12·5	—	—	—	9	177	14
"	River Sand	"	" 25	11·3	—	—	—	9	218	24
*Hoffman	Cockspur Beach	"	Sept. 22	14·0	4	64	—	—	—	—
"	River Sand	"	" 22	16·2	4	64	—		*32 days*	
Dyckerhoff	"	"	May 11	10·9	4	122	11	5	173	12
"	Cockspur Beach	"	" 11	12·9	4	112	4	5	147	24
Hoffman	"	"	" 12	—	—	—	—	16	88	22
"	River Sand	"	" 12	—	—	—	—	16	101	22

* Made in 1894, and were hand-tamped, all quantities by measure including water.

TABLE No. 25.—GIVING TESTS WITH A GREATER RATIO THAN 1 TO 1 OF SAND.

Cement.	Sand. Kind.	Grade.	Parts to 1 of Cement	Date Mixed.	Per Cent. Water.	7 Days. No. of Tests	7 Days. Mean Strain.	7 Days. Greatest Dif. from Mean.	56 Days. No. of Tests	56 Days. Mean Strain.	56 Days. Greatest Dif. from Mean.
ckerhoff	River sand	All	2	Mar. 13	9·3	4	100	4	5	135	8
"	"	30–40	2	" 18	12·1	4	82	16	3	123	5
ant	"	30–40	2	" 18	11·4	4	76	10	4	127	17
ckerhoff	Cockspur Beach	All	2	" 13	10·3	3	75	2	5	136	16
"	"	Held by 100	2	" 13	13·1	4	69	8	4	128	7
"	"	All	3	Apr. 25	13·5	—	—	—	10	98	12
"	River sand	"	3	" 25	10·4	—	—	—	20	100	13

TABLE No. 26.—SHOWING RELATIVE ACCURACY OF DIFFERENT EXPERIMENTERS.

Name of Experimenter.	Cement Used.	Parts of Sand to 1 of Cement	Tests. Age.	Tests. No. of Sets.	Tests. No. in Each Set.	Difference from Mean. Greatest.	Difference from Mean. Mean.	Per Cent. of Mean Dif. with Mean Strain.
Goddard and Ewans	Natural	1	7	1	10	13	13	101
" "	"	1	56	1	10	20	20	19
" "	Portland	3	7	1	10	28	28	44
" "	"	3	56	1	10	29	29	17
Abbott and Morrison	"	1	7	2	7	48	27	13
" "	"	1	60	2	7	44	42	15
" "	Natural	1	7	1	8	11	11	25
" "	"	1	60	1	8	4	4	5
Col. Poe	Portland	1	7	1	5	19	19	6
"	"	1	28	1	20	17	17	4
"	"	1	3 mo.	1	5	19	19	3
"	"	1½	7	1	10	29	29	6
"	"	1½	28	1	10	87	87	15
"	"	1½	3 mo.	1	10	76	76	10
"	"	2	3 mo.	5	5	57	35	6
"	"	3	7	1	5	9	9	6
"	"	3	28	1	5	32	16	6
"	Natural	0	28	3	7	17	12	6
"	"	2	3 mo.	10	5	36	25	8
"	"	1	7	3	5	24	14	16
"	"	1	28	3	5	68	34	14
"	"	1	3 mo.	2	5	54	37	9
A. S. Cooper	"	1	7	127	4	13	3½	9
"	"	1	56	135	4	34	10	10
"	Portland	1	7	82	4	28	11	7
"	"	1	56	104	4	60	16	7
"	"	2	7	5	4	16	8	10
"	"	2	56	5	4	17	11	8

RECENT ADVANCES IN BACTERIOLOGY WITH SPECIAL REFERENCE TO FOOD.*

By M. V. Ball, M.D.

The lecturer was introduced by the Secretary of the Institute, and spoke as follows:

Members of the Institute, Ladies and Gentlemen:

Bacteriology is, comparatively, a recent science. Only within the last ten years has it received any special attention, and within this time it has been given a place in the medical colleges and become recognised as an important department of knowledge.

Municipalties are forming laboratories for bacteriological work, and governments are instituting, on a large scale, researches, which must eventually be of great service to mankind. It is hardly to be expected that this subject should as yet be the common property of any but those who have made it a special study, and, therefore, a few words as to the nature of bacteria will not be out of place here.

Bacteria—from the Greek, meaning little or minute *rods*—is a term applied to various forms of organisms, microscopic in size, closely allied to the lower types of fungi and algæ; usually containing no chlorophyll; capable, in many instances, of propelling themselves with swift motion through the liquids in which they are found, and possessing, for this purpose, small cilia or flagella, like other types of microscopic plants.

They are very minute, requiring for their detection powerful lenses. Some idea of their size may be obtained from the statement that in the space of an inch from 15,000 to 20,000 can be placed side by side; but, growing together in large numbers as they do, such aggregations or colonies can readily be seen with the unaided eye, though the individual members of these colonies cannot be recognised.

*A lecture delivered before the Franklin Institute.

Bacteria are neither yeasts nor moulds, though possessing some of the characters of both.

The name, "bacteria," is not a good one, since other than rod-shaped organisms are collected under this group. Micrococci are globular or spherical bacteria; bacilli are the rod-shaped bacteria; and spirilli are spiral-formed or twisted bacteria. The colonies of one form are not to be distinguished from the others, but under the microscope the difference in shape is readily made out.

Bacteria are quick breeders; they multiply very rapidly. From one or two germs thousands are obtained in the course of a few hours. Some one has made the calculation that a single germ, if uninterrupted in its growth, would fill an ocean with its progeny in five days; but, fortunately, it digs its own grave by the poisons it generates, and so puts a limit to its growth. Some require several days before germination occurs. Two kinds of growth are known: one, in which reproduction is a process of fission or segmentation —one bacterium dividing itself into two, and each of these again sub-dividing—in reality, a continuation rather than a reproduction. And a second kind, known as sporulation. The germ gives rise to a spore, the spore then takes on a separate existence and, when the conditions favorable to maturation exist, it gives rise to a new germ.

Both forms of growth are utilised by the same bacterium. Under ordinary conditions it multiplies by fission when a permanent form is advantageous, or, as some think, when the soil is particularly rich, it produces spores. Spores have not been found in all bacteria; those possessing them are very resistant to all physical and chemical agencies, and withstand a high degree of heat without being destroyed.

For the different bacteria different conditions are necessary. Just as different plants require different kinds of soil and temperature, so these minute plants react differently and demand for their growth various surroundings. Some are not at all particular, and flourish on any sort of soil. They are like weeds that grow without attention; others again are as sensitive as hot-house plants, and require very carefully prepared media and a suitably regulated tempera-

ture. While some species demand a plentiful supply of oxygen, others grow only when this is excluded. Sunlight is usually destructive; an alkaline medium is better tolerated, than a neutral one, and acids are usually harmful. Moisture is necessary to growth.

Bacteria are not only disease-producers, they manufacture a host of products beneficial and essential to life. Life itself depends, in a great measure, upon the actions of these minute plants, which transform the complex molecules into their elements and make them fit for assimilation. If we could separate the industrial germs from the pathogenic or disease-producers, and domesticate the former, while we drive the latter out of existence, life would be more worth the living. This is gradually being attempted. Scientists are pointing out to us the properties of individual varieties, and showing us the methods of cultivation; while hygienists and therapeutists are doing all they can to exterminate the destroyers of life; so that we can already see how, in a few years, cholera will be a rare disease, and tuberculosis will no more be counted as the cause of one-fifth of all deaths.

What advances, if any, have been made in recent years as relates to the subject of *foods?* This is the topic I have been asked to consider: "Bacteria in their relation to food?"

First of all, I desire to take up the most important of foods, namely, *water*. Water is a food because it is necessary to sustain life, and considered in this sense air might also be classed as a food. But whether or not we call water a food, there are other reasons sufficient for us to make it a matter for consideration here.

Formerly a good water was one which came up to a certain chemical standard. The amount of chlorides and nitrates was determined, the hardness was computed and the total amount of solids ascertained. If a water did not contain more than 1 grain of chlorine per gallon, it was deemed potable. To-day, while chemical analysis still has an important place in the examination of water, it must go hand-in-hand with the biological or bacteriological analysis,

and we must know what sort of living organisms inhabit or are to be found in the specimen in question.

In the early days of bacteriology much stress was laid upon the number of bacteria found in a given quantity of water, and water containing more than 500 colonies to the cubic centimeter was deemed unfit for drinking, but now it is not so much the quantity as the quality of the bacteria that is looked for. One typhoid bacillus in a gallon of water is more dangerous than one million ordinary water bacteria; in fact, it would render the water impotable, while the latter would be harmless. Thus, the water analyst of to-day must be a competent bacteriologist as well as chemist; and to be a bacteriologist means a pathologist as well, for, in the investigation of bacteria, animals must be used for experiment, and the nature of the diseases caused by the bacteria must be known to the experimenter.

As in the earlier chemical analyses, the chlorine itself was not considered dangerous, but simply one of the indications of fæcal contamination, so in the bacterial examination, the presence of certain harmless germs may indicate dangerous contaminations. For instance, the presence of the bacilli commonly found in human fæces, which in themselves are non-pathogenic, would, of course, lead one to infer that human sewage had become mixed with the water supply.

The methods for the detection of typhoid bacilli in drinking-water leave much to be desired. The examination is often undertaken too late, when the bacilli are no longer present, or have been destroyed by the ordinary water bacteria. Typhoid bacilli do not live long in ordinary drinking-water; and yet, if the water be contaminated with them, a whole city or district can become infected in a short time, and when suspicion is directed to the water the germs have disappeared. To a less degree, this is likewise true of the cholera spirillum, which acts so quickly and is so deadly, and which usually is spread through the drinking-water.

A method lately described, and which promises success, is to take a large quantity of the suspected water (200 cubic centimeters), and add to it 2 grams of peptone and 2 grams of

chloride of sodium. Place this in the incubating oven, and, if cholera germs are present, they will multiply rapidly, so that they can readily be detected in the course of ten to twelve hours.

Bacteric examinations have been most useful in the testing of water filters, "germ-proof" filters, etc. Several filters are now in the market, which claim to be germ-proof; that is to say, which are supposed to prevent the passage of bacteria through the very minute pores of the filter. These filters are made of baked clay, infusorial earth, porcelain, etc. As a rule, they can deliver a germless water only for a few days in succession, when, owing to the activity of the bacteria which have collected on the surface of the filter cylinder, the pores are penetrated by the growth, and more bacteria than usual find their way into the water. This, in some cases, can be prevented by a careful cleansing, every few days, of the filter tube. All tubes are not alike, and some afford no protection at all, though they clarify the water by keeping out the grosser particles of dirt.

Filters are best tested by adding to the water, before filtration, some well-known bacterium (usually the red pigment-forming and rapid-growing *Bacillus prodigiosus*) making cultures before and then after filtration. If, under suitable precautions, the germ is found present in the filtered water, the filter is imperfect. In the testing of large filtering plants, where it is not expected that the water will be perfectly free from germs, quantitative methods must be used, in order to tell what percentage of bacteria is left behind.

These large filtering plants are in use in several cities, and, it seems to me, they are of doubtful value only. It is true, the water is more pleasing to the eye, and, for toilet and laundry purposes, more valuable; but if the water is contaminated with disease germs there is no surety that they will be among the 50 per cent. filtered out. They are just as liable to pass through as the others, and such a water is not safe. From the sanitary point of view, filtering plants are only valuable when the water is uncontaminated by human sewage; and to erect such a plant in our city, without paying any attention to the source of our water

supply, and even allowing it to be polluted along its whole course, will hardly reduce the death rate, though it may add to the æsthetic quality of the water.

On an average, 500 deaths occur every year in this city from typhoid fever. This means at least 6,000 cases. From an economic point of view, the persons affected are the most valuable members of society, chiefly young adults between the ages of 20 and 40. The expense, in loss of time, medical attendance, etc., is at least $100 for each case, a total cost of $600,000 yearly from this one disease, to say nothing about the loss of life; and all because we are obliged to drink the sewage of half a dozen towns above us, and the drainings from graveyards and pigsties along the banks of the Schuylkill.

And while we are thus treated by the cities above us, we send our sewage to the towns below. Some strict measures must be put into practice, which will prevent this pollution of our drinking-water.

The second important article of food, with which bacteriologists have busied themselves, is *milk*. A good milk must contain a certain amount of solids and fat, but it can be adulterated with far more harmful matters than water, and these other adulterations are not so readily detected.

A few hours after milking, ordinary milk has been found to contain 1,000,000 germs to the cubic centimeter. How did these get in?

If the udders of the cow are not kept clean, the first flow of milk will wash the dirt into the milking-pan. If the man who milks the cow is uncleanly in his habits, using dirty hands in the operation, the milk receives this dirt. If the stall is the place for milking, and other animals are moving about, the dust raised falls into the open pail and contaminates the fluid; and, finally, in the transportation from the farmer to the collector, from the dealer to the customer, a hundred opportunities present themselves for the entrance of bacteria, which, when once in, thrive abundantly, the milk being a rich and suitable soil for their growth.

In the markets of Halle, Berlin and Leipsic, Ranke succeeded in finding, in the milk exposed for sale, considerable

quantities of cow-dung, which, of course, greatly increased the number of germs to the cubic centimeter—in one case up to 169,000,000.

Bolle, the milkman of Berlin, who sells 60,000 quarts of milk daily, has endeavored to make his large establishment conform to scientific requirements. He has a competent bacteriologist, who makes frequent examinations of the product. The milk is obtained from such dairies only as are under his inspection. Separate examinations are made of the different herds, so as to trace disease to its proper source. The collected milk is filtered each day through immense sieves of gravel, which have first been subjected to a high degree of heat in order to sterilise them. The milk is forced through from below upwards, and collected in proper vessels. Four thousand quarts pass through such a filter in one hour. By this means the dirt is removed and with it about 50 per cent. of the bacteria present.

While this filtered milk keeps longer than the unfiltered, and is more readily sterilised, it is just as dangerous if disease germs were originally present, since, as was stated above, in connection with the filtration of water, the disease germs are just as likely to be among the 50 per cent. that pass through as to be among those that remain.

In order to render milk completely sterile, it must be subjected to such a degree of heat as will coagulate the casein and make the product undesirable in other ways. If, however, great care be exercised in the milking, and sterilisation be carried on at once or shortly after, a very moderate degree of heat will be sufficient to make the milk entirely sterile.

One of the bacteria that is often found in milk has very resistant spores, and, therefore, if milk becomes contaminated by exposure to the dust and dirt of the air or stall, ordinary warming or heating, as is done when milk is Pasteurised (so-called sterilised milk), will not suffice to destroy these spores.

Milk is often sold to us in bottles, and one would imagine that such a product was reasonably clean; but this bottling is done in a very careless way, often in the street by some

ignorant delivery boy, while the street sweeper is raising clouds of dust, some of which lodges in the exposed milk.

In one dairy in Dresden, Germany, all the milk comes from stall-fed, or dry-fed, cows, experience having shown that such cows give a product that is less variable, and contains fewer germs, and sours less speedily than when they are fed on fresh grass. Great care is taken in the milking, and especial attention is paid to the cleanliness of the employés. After the milking, the milk is placed in coolers, where it remains two hours, at a temperature of 10° C. Then it is put into a centrifuge, in order to separate the dirt that might accidentally have fallen in. It is now warmed up to 65° C. (Pasteurised), and collected in half-pint sterilised bottles, and the filled bottles again heated for one hour and three-quarters, at 65° C., and quickly cooled. Such milk is reasonably sterile, and the method is the only one to be recommended.

Unless all these steps are followed the milk cannot be considered sterile.

What danger is there in milk from tuberculous cows? This is a question which, just at present, is receiving considerable attention.

Tuberculosis is very frequent among cattle. In the slaughter-houses of Berlin, out of 142,000 head of cattle, 21,000, or 15 per cent., were found to be tubercular. In all Prussia 10 per cent. of all the cattle slaughtered annually are found to be affected with this disease. Some veterinarians claim that 30 per cent. of all cows are infected, and that a herd cannot be found that is entirely free from the disease. From this, one can readily see the importance of this question. In New York City 900,000 quarts of milk are consumed daily. Consumption is likewise a very common disease, causing from one-third to one-fourth of all the deaths among adults, and many, if not the greater number of the diseases of children are tubercular in origin.

Is the cow an enemy to man? Are we warranted in accusing the milk of consumptive cows as being the cause of consumption in man? The last word has not yet been said on this subject. We can only give the opinions of authori-

ties, the present beliefs gained from the knowledge at hand; and these are that, if the udders of a cow are unaffected, if there is no local tuberculosis, no bacilli are to be found in the milk, the milk may be considered safe. Yet, later investigations have shown that the toxic principles of bacteria find their way into the milk, that the milk of an animal rendered immune to diphtheria or tetanus has the same properties as the serum of the blood, and can protect other animals. If this is uncontroverted, then the milk of tuberculous or consumptive cows may have within it the products of the tubercle bacilli, and such milk may have the same effect upon the human organism as these products obtained artificially, or from cultures outside of the body. The discussion on the benefits or ill effects of *tuberculin* has not yet been closed, and it is impossible to say, therefore, whether such milk, *i. e.*, milk containing tuberculin, is positively harmless or dangerous.

In Paris all cows whose milk is offered for sale must be tested with tuberculin to prove their freedom from tuberculosis. Our own Board of Health has strongly advocated a similar test.

Tuberculin has been found reliable in the greater number of cases; *i. e.*, if an animal showed signs of temperature rise after the injection of the tuberculin, the disease has always been found present; but the disease has been found when no rise has occurred, so that it is a positive test only. Tuberculosis is present whenever there is a rise of temperature, but it is not necessarily absent if no reaction occurs.

Because tuberculosis is so very frequent, because 2,700 deaths of adults between 15 and 45 occur every year in this city alone from this one disease, it behooves us to try every measure that holds out the slightest chance of success in reducing this awful mortality, and, therefore, if only as an experiment, it would be worth the time and money to destroy every suspicious animal, and thus prevent the sale of all milk save that obtained from perfectly sound cows. Any reduction in the death rate from this disease will be a step in advance, and our efforts should be directed to this end at all cost.

If the milk of consumptive cows is dangerous, then cheese and butter made from such milk is likewise dangerous, and the sale of such should be equally guarded against.

In Germany, butter has been made from sterilised milk by the addition of pure cultures of certain bacteria, which have the power of coagulating the milk. Such butter has a constant flavor, and does not deteriorate so quickly as butter produced in the ordinary way.

To summarise in regard to milk, we can say that (1) a careful inspection of the dairy; (2) a close examination of the cattle; and (3) cleanliness in the transportation and sale, must be rigorously enforced to safeguard the public health.

As regards meat, little has been said or done. Meat is rarely used in the raw state, and cooking generally renders ineffective the germs likely to be found present.

In the cities of Europe, careful inspection is practiced at the abattoirs, and meat from diseased cattle is excluded or sold under restrictions. Meat-shops are likewise kept very clean, and the meat is seldom exposed in filthy warehouses. In our own cities some of the meat offered for sale on the stands and in street shops is most unfit for food,—some of it, indeed, in a state of putrefaction. Some cities have laws which make such meat liable to seizure, but these laws are seldom operative.

The advances in fermentation deserve attention, for, though they are not, strictly speaking, connected with our subject, yet so closely are the yeasts related to bacteria, and so similar are the methods of cultivation, that any discoveries in the one field are sure to be of value in the other. Bacteria have always been a disturbing element in industrial fermentations, and expensive methods have been resorted to, to prevent the entrance of disease germs—disease, here, meaning impure or improper germs.

The yeasts were formerly considered as few in number—as alcohol-producers and non-alcohol-producers—no serious efforts were made to obtain pure cultures, but the mashes and brews were kept under such conditions that the foreign germs were prevented from growing or multiplying. Beer

was stored in ice-cellars, whiskey was subjected to special temperatures, and other elaborate measures were used which now can be dispensed with if we start with pure cultures of yeasts at the beginning, and avoid the entrance of impurities from air, water, etc.

In Denmark, Hansen (and from him a school has originated) pays great attention to the cultivation of pure yeasts. Brewers can obtain from the laboratories such pure cultures and thereby insure a definite alcoholic strength, a constant flavor, and a product that will not deteriorate, even under varying conditions of temperature, etc.

By experimenting with different combinations of yeasts, various degrees of bitterness and different aromas can be developed.

Wines depend very largely for their bouquet, not so much upon the grape as upon the particular germ or germs used in the fermentation of the juice. Experimenters have obtained, with the same kind of grape, a half-dozen different wines by using as many different yeasts. As the pigment yeasts produce various colors, so the yeasts used in fermentation give rise to various ethers, and these ethers give the wine its peculiar bouquet.

We should expect to obtain a Rhine wine from a New Jersey grape by using the yeasts which are common in the Rhine region, or on the Rhine grape. Even out of apple most, a good-tasting wine has been produced by the use of particular cultures of yeast.

These researches have revolutionised German brewing, and the large breweries now have competent bacteriologists in their employ, who attend to the cultivation of their yeasts.

The spaces or holes peculiar to certain *cheeses* are due to the evolution of gases during the ripening process. These gases are produced by certain bacteria, and by using pure cultures of these gas-forming bacteria in the manufacture of cheese, these air-spaces will always occur. The odor of cheese is likewise due to bacteria, and special flavors can thus be obtained at will by using the particular germs.

Bread made from pure yeast will be found to be more

digestible, to be lighter and to possess a sweeter flavor. Too little attention has been paid to this in baking. Mixtures of yeasts and bacteria are used, and the baking powder or the flour is blamed for poor results. Sour bread is usually due to a poor quality or impure kind of yeast. The soil out of which we obtain such important food-stuffs has been studied bacterially and has been found to contain peculiar germs, which are all necessary to the growth of the plant. These are the so-called nitrogen-forming bacteria.

They convert the nitrates into nitrites, the oxidisers of organic material, more necessary to the well-being of vegetable life than anything else. Instead of using tons of fertilisers, the agriculturist of the future will cover his fields with cultures of the nitrogen germs and obtain better results. We will even have special germs for special plants. The science of agriculture is yet in its infancy, if we may believe the promises held out to it by bacteriology. Even at present the agricultural colleges are equipping themselves with laboratories for bacteriological research.

Thus I have tried to show that the recent advances in this science are as nothing compared with what may yet be expected; that in these germs, microbes and bacteria, mankind has deadly foes and also important friends; that we must do all we can to rid ourselves of the former and make the latter our willing slaves.

ALUMINIUM SOLDERS.*

By Joseph Richards.

Very soon after Deville first made aluminium on a large scale, it was found that it was a most difficult problem to solder it satisfactorily. The ordinary alloys used for soldering were found not to attach themselves to aluminium, despite every usual precaution, and it was seen that unusual solders must be devised to meet this unusual problem. M. Christofle, the goldsmith, of Paris, gave the subject

*Abstract of remarks made before the Institute.

his special attention, and discovered that aluminium was wetted by, and could therefore be soldered with, either pure zinc or pure tin. It is indeed true that both these metals hold firmly to the aluminium, but the zinc seam is brittle and crystalline, will not stand working, and discolors badly in a short time, while the tin seam has the disadvantage of disintegrating and falling to pieces in a few weeks. This latter phenomenon is due to the fact that certain alloys of tin and aluminium will decompose spontaneously by the action of the air. This is particularly true of tin containing small proportions of aluminium, up to 10 per cent.; for, if a bar of such alloy is left in the air, and portions are broken off at regular intervals, a change will be visible in the section, proceeding from the outside towards the center; and while at first the alloy is strong and tough, it gradually becomes more and more friable until, at length, when the change has reached the center, it breaks like a pipe-stem. I have observed a bar, $\frac{1}{16}$ inch thick, to become decomposed all through in three weeks, and on thinner sections the effect is still more marked. Tin containing 0·5 per cent. of aluminium was rolled by a Philadelphia maker of tin-foil into foil, 0·001 inch thick, and, while it rolled beautifully, yet in two hours thereafter the whole sheet was as brittle as glass. Now, bearing these facts in mind, it can easily be understood why a joint soldered with tin falls apart. The tin attaches itself to the aluminium by forming an alloy at the junction, and this alloy decomposes in a short time.

It would be a serious task to catalogue all the different metallic mixtures which have been proposed for soldering aluminium since M. Christofle's experiments in 1855. Alloys of aluminium and zinc were tried by the Tissier Bros., but were found to be too brittle. M. Hulot proposed to first plate the aluminium at the joint with copper, and to solder the coppered surfaces with ordinary solder.

At length, the Société d' Encouragement offered a prize for a solution of this problem, which was awarded to Mourey, a Parisian goldsmith. His best solders were alloys of aluminium and zinc, to which small proportions of copper were added, to give them toughness. The chief difficulty

with these solders is their high melting-point; the zinc, which melts only at incipient red heat, being the most easily fusible ingredient.

For brazing and blow-pipe work, such high-melting alloys can be used, and the addition of a little silver improves them still more; but none of them can be regarded as convenient for use with the soldering-iron.

It has been claimed that by using silver chloride as a flux, aluminium can be soldered in the ordinary way with ordinary tin solder; but this method has not proved satisfactory in practice, and, even if it were, the flux is too expensive.

Starting with a full understanding of the difficulties of the problem, and a knowledge of what had been previously tried and found wanting, I proceeded with the object of finding, if possible, a solder which should have the following qualifications:

(1) It must wet the aluminium and adhere firmly:

(2) It must not disintegrate after exposure to the air:

(3) It must be as malleable and strong as aluminium:

(4) It must have a low melting-point, so as to be easily worked with a soldering-iron:

(5) It must have the same color as aluminium, and not change color; and

(6) It must be cheap enough for general use.

After experimenting about two years, it was finally found that an alloy of zinc and tin in certain proportions, containing a little aluminium and some *phosphorus*, realised almost every qualification. The alloy used for some time was made by fusing together:

	Parts.
Aluminium	1
Ten per cent. phosphor-tin	1
Zinc	8
Tin	32

It was found, however, that, on re-melting this solder, a more fusible alloy liquated away from it. It appeared reasonable to assume that this more fusible part was a true alloy of zinc and tin, and, therefore, a more stable compound. This fusible portion was also found to solder better

than the original mixture. This liquated solder was therefore analysed, with the result that its composition was found to be very close to that expressed by the formula Sn_4Zn_3. The solder which I now use is made to correspond closely to this formula. It is obtained by using the ingredients in the proportions 1, 1, 11, 29, instead of 1, 1, 8, 32, as previously described. The percentage composition of the several alloys described may be thus compared:

	Original Solder.	Found in the Liquated Alloy.	The Formula Sn_4Zn_3 Calls for	Solder, as now Made, Contains	
Aluminium . .	2·38	—	—	2·38	Zinc + Aluminium, 28·57 per cent.
Zinc	19·04	—	29·3	26·19	
Tin	78·34	71·65	70·7	71·19	
Phosphorus . .	0·24	—	—	0·24	

The percentage of zinc in the new solder is lower than called for by the formula Sn_4Zn_3; but since aluminium and zinc are metals having many physical analogies, it was thought advisable to bring the combined percentage of these up to that required for the zinc alone. Further, as the tin is most liable to lose by oxidation during the mixing of the solder, it was thought best to have it slightly in excess.

The result of these investigations is before you in the specimens of soldering presented for your inspection. As practical usefulness is a fair criterion of the value of an invention, I may be permitted to mention that this solder has come largely into use in Germany, Switzerland, England and our own country.

It must be remembered that at present the demand for an aluminium solder is limited. About 4 tons of aluminium are now produced daily in the world, but fully 75 per cent. of this is used up in the steel industry and in making alloys; while, of the remaining 25 per cent., which is rolled, spun, cast, or stamped into pure aluminium articles, probably not 10 per cent. is in such shape as to require soldering. Assuming, then, an average of 200 pounds a day of aluminium

articles to be soldered, a daily supply of a very few pounds of solder would meet the entire demand.

It does not require the prophetic eye, however, to see that the 1,000 tons of aluminium produced during 1893 will probably reach 10,000 tons a year within the next ten years, and that with increased production the demand for a good solder must correspondingly increase.

In conclusion, I wish to add that I am indebted to my son, Dr. J. W. Richards, of Lehigh University, for chemical analyses and other aid in preparing this solder.

On the Growth and Sustaining Power of Ice.

By P. Vedel, C. E., M. West. Soc. Eng.

When, in the fall, the temperature of the air decreases, the water gets gradually cooled off from the surface. The colder surface water sinks down and the warmer water from below rises, gets cooled off at the surface and sinks again to let some relatively warmer water from below rise in its turn, and so on continually, as long as the colder water has a greater specific gravity than the warmer. So far, this process of cooling off from the upper surface is parallel to the heating of the water in a boiler by a similar circulation from the under surface. But it is known that water, unlike any other fluid, has its maximum density at a certain temperature, and expands from that point whether the temperature decreases or increases. For pure, fresh water, the specific gravity increases from 1 at 62° F., to its maximum 1·00112 at 39°·2 F. (4° C.); for sea water, the corresponding temperature is 25⅘°–27° F. When, therefore, the surface water is cooled off to 39°·2 F., it sinks, not to rise again unless either heat or cold is conveyed to it at the bottom. The water which has taken its place at the surface sinks, to remain below at that same temperature, and, consequently, when the whole water body is cooled down to 39°·2 F., all circula-

tion stops. The only way in which the water can then be further cooled off from the surface is by conduction, but the conductivity of water being small, this is a very slow process compared with the former.

When the temperature of the surface-layer reaches 32° F., ice is generally formed in fresh water; the freezing point of sea water is at 27°–28° F. But rapid running streams may not be ice-bound at much lower temperatures, and in perfectly calm water the temperature may go down considerably, perhaps 10°–12° below the freezing point, before the formation of ice, which then takes place suddenly by the slightest motion, caused, for instance, by a gust of wind or the introduction of an ice crystal. The heat of liquefaction, being set free, raises the temperature of the ice to 32° F., but, immediately after, its upper surface partakes of the variations of the temperature of the air. The ice cover protects the water from agitation by winds and from further cooling, inasmuch as the heat from the water now has to be conveyed the greater distance, through ice and through snow, which may have fallen upon it.

But the bottom of a lake or a river, if not too shallow, has a temperature corresponding to that of the earth crust at the same depth. At 6½ feet below the surface the annual mean temperature of the soil was 55° F., when that of the air was 50°·4 F., and the extreme variations were respectively 24°·7 and 84° F. At 50–60 feet depth the temperature is approximately uniform, 50°–60° F. in temperate climates, and increasing about 1° F. for each additional 50–60 feet. But at less depth the temperature will change with the seasons, only so slowly that maximum below may be reached several months after the summer above. The bottom will then give off heat to the water nearest to it and currents may arise. Thus, the temperature may be 33° directly under the ice, 39° about 6 feet below, and 42° F. at the bottom, 25 feet below the surface. On the other hand, the average temperature of the water beneath the ice is sometimes found less than 39°·2, although the cold has not lasted long enough to have produced it by conduction only; thus, in some of the Scot-

tish lochs, temperatures of 34°–37°–38° F. have been measured. An explanation* of this phenomenon is sought in differences in temperature of the air on different points of the lake. An ice-fringe first being formed near shore, currents are produced by the different densities of the water under the ice and outside it, a surface current carrying water from shore towards the center of the lake, where it is cooled off by the air, and undercurrents carrying it back towards shore. Also, at the bottom of open, running water, especially on shoals, the temperature may sink to, or—perhaps by radiation—below, that at the surface, and give rise to the formation of anchor or ground ice ("groundgru," "frozee"), the current at the bottom being retarded by the friction.

The specific gravity of ice lies between 0·90 and 0·95, and may as an average be taken as 0·92. In freezing, water therefore increases in volume from $\frac{1}{9}$ to $\frac{1}{11}$, or as an average $\frac{1}{11}$; and, when floating, the ice will be immersed about $\frac{11}{12}$, while $\frac{1}{12}$ of its mass will be above water. The formation of ice is, perhaps, rather an intermittent than a continuous process; but it seems to be proved that the growth always is downwards, due to the freezing of the water under the ice, and not of vapors condensed on its upper surface. Still, such vapors escaping through or from the ice, or the so-called "frost smoke," may produce those beautiful hexagonal stellate crystals, or six-leaved ice flowers, which in cold weather are sometimes found on its surface. And when by a rise of the river the ice-sheet is held down by its sides, and thus, or by rain or melting snow, or in any other way, its surface becomes covered with water, then a subsequent frost will, of course, increase its thickness by a growth upwards. But such growth, being accidental and due to particular, incalculable circumstances, may here be left out of consideration.

The rate at which the ice is formed and grows depends upon the temperature of the air and the condition of the water, whether still or running, in a rock- or mud-bed, with

**Nature*, 1879.

or without springs in the bottom, salt or fresh, pure, or polluted with organic, putrescent matter. The specific gravities of ice and water, specific and latent heats, coefficients of conduction and radiation, etc., all influence the formation of ice.

Let D be depth of water under the ice, H the thickness of the ice-sheet, $d\,H$ its increase in the time $d\,\tau$, the corresponding decrease of D being less than $d\,H$ on account of the expansion in freezing; the temperature of the air be T, of the upper surface of the ice t, of its under surface as of the upper layer of the water that of the freezing point, and at the bottom that of maximum density.* For simplicity's sake all dimensions are expressed in meters, an area of one square meter of the ice-sheet being considered, and all temperatures in Centigrade. Before the increase $d\,H$ took place the water contained

$$\frac{0+4}{2}\,s_w\,\delta_w\,D + l_w\,\delta_w\,D$$

heat units, and the ice

$$\frac{0+t}{2}\,s_1\,\delta_1\,H \text{ h. u.}$$

in which s_w and s_1 are, respectively, the specific heats of water and ice, both supposed to be constant, δ_w and δ_1 their respective specific gravities, corresponding to the average temperatures

$$\frac{0+4}{2} \text{ and } \frac{0+t}{2}$$

and l_w the latent heat of water. After the formation of the layer $d\,H$ the water and ice together contain:

$$\frac{0+4}{2}\,s_w\,\delta_w\left(D-\frac{\delta_1}{\delta_w}\,d\,H\right) + l_w\,\delta_w\left(D-\frac{\delta_1}{\delta_w}\,d\,H\right)$$

$$+\frac{0+t}{2}\,s_1\,\delta_1\,(H+d\,H) \text{ h. u.}$$

* This is only approximately correct. It lies between that temperature and the freezing point. But the influence upon the result is unimportant. The temperature of the under side of the ice is, perhaps, also different from that of the water.

Hence the whole system has lost:

$$2 s_w \delta_1 d H + l_w \delta_1 d H - \frac{t}{2} s_1 \delta_1 d H \text{ h. u.} \quad (1)$$

By conduction there passes in the time $d\tau$ through the ice $C(0 - t)\, d\tau$ or:

$$- C t\, d\tau \text{ h. u.} \quad (2)$$

where:

$$\frac{1}{C} = \frac{1}{\frac{a}{t - T}} + \frac{H}{c} = \frac{t - T}{a} + \frac{H}{c_1}$$

where a is the number of heat units conveyed by radiation to the air or by convection with it, and c_1 is the coefficient of conduction of the ice, both per hour.

Now, (2) must be the same as $a\, d\tau$, and the same as (1). Hence:

$$a = - C t = - \frac{t}{\frac{t - T}{a} + \frac{H}{c_1}} \quad \therefore \quad a = \frac{c_1}{H}(T - 2t)$$

and:

$$(2 s_w + l_w - \frac{t}{2} s_1)\, \delta_1 d H = a\, d\tau = \frac{c_1}{H}(T - 2t)\, d\tau \quad (3)$$

To determine the temperature, t, we must find another expression for a. By radiation to the air, escapes per hour from the ice, according to Dulong and Petit:*

$$125\, r\,(1{\cdot}0077^{t} - 1{\cdot}0077^{T}) \text{ h. u.}$$

where r is the coefficient of radiation And, by convection, there is carried away by the air per hour:

$$0{\cdot}55\, b\,(t - T)^{1{\cdot}233} \text{ h. u.}$$

where b is the coefficient of contact. The total amount of heat units given off by the ice to the air is, therefore:

$$a = \frac{c_1}{H}(T - 2t) = 125\, r\,(1{\cdot}0077^{t} - 1{\cdot}0077^{T}) + 0{\cdot}55\, b\,(t - T)^{1{\cdot}233} \quad (4)$$

whence t.

* Hütte: "Ingenieurs Taschenbuch," Berlin, 1892.

The growth of the ice is thus given by equation (3), in connection with (4). Developing in the latter the exponential and binomial terms:

$$1{\cdot}0077^t = 1 + \frac{hyp.\ log.\ 1{\cdot}0077}{1}\, t + \ldots.$$

$$= 1 + 0{\cdot}01\, t + 0{\cdot}00005\, t^2 + \ldots.$$

$$(1 - \frac{t}{T})^{1{\cdot}233} = 1 - \frac{1{\cdot}233}{1}\frac{t}{T} + \ldots.$$

$$= 1 - 1{\cdot}233\, \frac{t}{T} + 0{\cdot}144\, (\frac{t}{T})^2 + \ldots.$$

we find, approximately:

$$\frac{t}{T} = \frac{1{\cdot}25\, r + 0{\cdot}55\, b\, (-T)^{0{\cdot}233} + \frac{c_1}{H}}{1{\cdot}25\, r + 0{\cdot}61\, b\, (-T)^{0{\cdot}233} + 2\frac{c_1}{H}}$$

which for $r = 5{\cdot}31$, $b = 5$, $c_1 = 0{\cdot}0024$, H lying between $0{\cdot}01$ and 1, and T between 0 and $-50°$, varies from $0{\cdot}93$ to $1{\cdot}00$. Hence

$$t = 0{\cdot}95\, T \qquad (5)$$

Returning now to equation (3), we may consider

$$\frac{t}{2}\, s_1$$

as constant, taking an average value for it. Hence, by integration:

$$\int_0^H (2\, s_w + l_w - \frac{t}{2}\, s_1)\, \delta_1\, H\, d\, H = \int_0^{24_n} c_1\, (T - 2\, t)\, d\, \tau \qquad (6)$$

n being the number of days since the first formation of ice. And by (5):

$$(2\, s_w + l_w - \frac{t}{2}\, s_1)\, \delta_1\, \frac{H^2}{2} = 0{\cdot}9\, c_1 \sum_0^{24_n} (-T)$$

$$= 21{\cdot}6\, c_1 \sum_0^{n} (-T)$$

T being the average temperature for 24 hours. Hence:

$$H^2 = \frac{43\, c_1 \sum_0^n (-T)}{(2\, s_w + l_w - \frac{t}{2} s_1)\, \delta_1} \qquad (7)$$

which determines the thickness of the ice by the sum of the daily mean temperatures. The physical constants of ice and water which enter into this expression are, approximately:

$$s_w = 1{\cdot}0224, \qquad s_1 = 0{\cdot}505, \qquad \delta_1 = 0{\cdot}92, \qquad l_w = 79{\cdot}25,$$

and, therefore:

$$H^2 = \frac{46{\cdot}7\, c_1 \sum_0^n (-T)}{81{\cdot}3 - 0{\cdot}25\, t} \qquad (7^1)$$

or, approximately:

$$H^2 = \frac{46{\cdot}7}{83}\, c_1 \sum_0^n (-T) = 0{\cdot}56\, c_1 \sum_0^n (-T)$$

The coefficient c_1 is, unfortunately, only imperfectly known. The heat-transmitting power of ice has been stated to be 0·06 times that of air, for which the coefficient of conduction is 0·04. This would make $c_1 = 0{\cdot}0024$, as assumed above. But, taking the resistance to the passage of heat from the water to the ice into consideration, the coefficient should be taken somewhat less, or, say, $c_1 = 0{\cdot}002$. This will make:

$$H^2 = 0{\cdot}00112 \sum_0^n (-T)$$

where H is expressed in meters, T in degrees Centigrade. Transforming to inches and degrees Fahrenheit, we deduce:

$$H^2 = 0{\cdot}96 \sum_0^n (32 - T) \qquad (8)$$

For salt water, with the freezing point at 27° and temperature of maximum density at 26°, this expression will be altered to:

$$H^2 = 1{\cdot}02 \sum_0^n (27 - T) \qquad (8^1)$$

As there are always springs and currents in the water, convection of heat from the bottom and more or less snow on the surface of the ice, the rate of increase of thickness must necessarily fall short of the theoretical. Evaporation has also the same effect. This has not been taken into consideration, and, according to the Boston Water Works experiments, may amount to 0·06 inch per day. In the general formula:

$$H^2 = k \sum_{0}^{n} (f - T) \qquad (9)$$

where f is the freezing temperature, 0° C. or 32° F. for fresh water, and — 2°·5 C. or 27°–28° F. for salt water, the coefficient k, the maximum of which, for inches and degrees Fahrenheit, is about 1, must always be considerably less than this.

In studying the growth of ice in the Arctic Sea, Dr. Stefan* deduced a formula which differs slightly from (7), to wit:

$$H^2 = \frac{2\,c_1 \sum_{0}^{24n} (- T)}{(l_w + \frac{t}{3} s_1)\,\delta_1}$$

or, as he writes it:

$$H^2 \left(1 + \frac{s_1\, t}{3\, l_w}\right) = \frac{2\, c_1}{l_w\, \delta_1} \sum_{0}^{24n} (- T)$$

Observations from Arctic expeditions to nine different localities all agreed closely with formula (9), giving nearly constant values for k. With inch, Fahrenheit degree, and the day of twenty-four hours as units, its average value was:

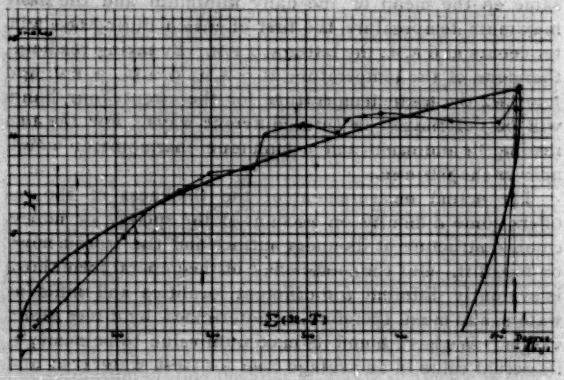
$$k = 0{\cdot}87$$

with extreme values 0·70 and 0·92; with centimeter and Centigrade degree as units, it is:

$$k = 10{\cdot}09$$

* *Nature*, **40**, 1889.

A series of careful observations were taken by the writer during the winter 1893–4 on a side branch of the Desplaines River, near Willow Springs, Ill., for a growth of ice from 0 to 12½ inches. The river-bed consists of soft mud and fine shells to a varying but generally considerable depth, with numerous springs in the bottom. No currents could disturb the water in the side branch but those arising from a variation of the water level of some 2 or 3 feet. A heavy snowfall occurred once or twice, covering the ice until swept away by the wind. The coefficient k could, therefore, not be expected to come anywhere near its max-



imum, 0·96, but must be only a fraction thereof. By the method of least squares it is found to be:

$$k = 0{\cdot}30$$

The curve (see *Fig.*) plotted from the observed values of H and $\Sigma(32 - T)$ differs not more than could be expected from the parabola, the mean error on H being 0·8 inch.

On a lake, 15 inches of ice were formed* during twenty-one days of nearly uniform temperature, ranging from

* *Am. Journ. of Science and Arts*, **3**, 179.

— 7° to + 11° F. Taking, as an average, + 2° F. we find for the coefficient:

$$k = 0.36$$

For the practical use of the formula (9) and for determining the coefficient k, it is necessary to keep an account of the daily mean temperatures. The use of a self-registering thermometer, or the taking of hourly readings day and night, will seldom be convenient and are altogether unnecessary. For it has been found* for temperate climates that in the winter months the daily mean temperature is the same as the temperature at 9 A.M. and at 7.30 P.M.; also that it is the same as the mean of the daily minimum and the daily maximum temperature, the first of which during the winter occurs at 6 A.M., the latter at 2 P.M. By taking readings, therefore, of the temperature at 6 A.M., 9 A.M., 2 P.M. and 7.30 P.M., the mean temperature for the twenty-four hours will be determined in three different ways. For the two readings a minimum- and a maximum-thermometer would answer the purpose.

The actual measurement of the thickness of the ice offers some difficulty on account of the spongy or honeycombed structure at its under surface and the frozen snow on top of it. But the coefficient k of the general formula (9) is evidently different for different localities and different waters, and must, therefore, be determined by direct observation. We have found its maximum value to be nearly 1, its actual value in an average case for fresh water 0.30, and for salt water in the Arctics 0.87, and often meet with cases of swift-running rivers or specially heated waters where it is 0 or approximately so. The corresponding relative values of H are 1, 0.55 and 0.93. In absence of any observations, sound judgment must assign a value to k.

When the temperature rises above the freezing point and thaw sets in, the ice thaws away from the upper surface or from the side exposed to the heat, and consequently will thaw much faster than it froze before. Continuing the curve (comp. *Fig.*) after the thaw, when $\triangle T$ is negative, it

Journ. Frank. Inst.*, **23 and **26**.

will fall faster than it rose, and finally will reach the T axis long before the sum of thawing temperatures equals the sum of freezing temperatures expended in the production of the ice. As the colder air, on account of its greater specific gravity, will remain near the surface of the ice, it will take some time, and the sum of temperatures of the air measured some distance above that level, will have reached a certain amount before the ice begins to thaw. From that time the relation between the decrease of the thickness of the ice, $H_1 - H$, and the sum of temperatures may, by a similar procedure as above, be found to be approximately that of the co-ordinates of a parabola.*

The sudden disappearance of the ice on various lakes has often caused surprise. On Lake Champlain an expanse of ice 12 inches thick has been known to vanish during a single night. It has been found in such cases that the ice was transformed from a solid homogeneous mass into an aggregation of irregular, prismatic needles, placed vertically, close together, and with but a trifling cohesion to one another. This is the "penknife-ice" which Captain Parry met with in the Arctics. The needles are perhaps ½ to 1½ inches broad in the middle, and 5 to 10 inches long, or as long as the ice sheet is thick. When first an open strip of water is formed, these needles, either by themselves or by the wash of the water, fall asunder; they will tip over and, their whole surface being exposed to the warmer water, they will thaw away quickly. The formation of this peculiar structure of the ice is somewhat shrouded in mystery; but it seems to be due to a certain succession of temperature variations with the subsequent expansions and contractions of the ice. This does not explain, perhaps, why sometimes penknife-ice is formed where only a short distance away the ice is compact.

When water freezes it expands with great force, and exerts a pressure which Trautwine estimates at not less

* Approximately:

$$(H_1 - H)^2 = k_1 \sum_{0}^{n} (T - 32)$$

where k_1 perhaps is about 2·6.

than 30,000 pounds per square inch. The ice-sheet, therefore, when formed on a lake, crowds its edge against the shore. With a fall of temperature the ice must contract; but being held at its edges by the friction on the sides, it cracks and opens into vertical fissures, or is, through its whole body, subjected to interior horizontal stresses. Therefore, the natural cleavage of the ice is always in vertical planes. Water enters these fissures for at least ten-elevenths of their depth, and often, lifted by capillarity, to the upper surface of the ice, in freezing it fills them with compact ice. When the temperature again rises, the whole ice-body expands and, the old fissures being filled, a compression takes place which may produce new fractures. At the same time a thrust or shove is exerted towards shore, by which the ice is forced up the side-slopes, carrying with it boulders and loose material. A subsequent fall of temperature gives rise to new cracks, the water in them freezes and warmer weather again produces a shoreward thrust. Thus, the "shore wall" of the geologists is formed and the ice may be piled up to great heights. Having been exposed repeatedly to such expansions and contractions, the ice is strained in a similar way to that of the well-known glass toys, known as Prince Rupert drops. By a sudden shaking or percussion, it (the ice) may, like the glass drops, fall to pieces, forming a lot of needles very much like the prismatic vertical bodies into which granite, basalt or other plutonic rocks may cleave, this prismatic structure, perpendicular to the cooling surface, being common to other materials slowly solidified from a state of fusion.

The rate of expansion and contraction per degree F. for ice was found by Dumble to be 0·00000765 (0·0000033 at the freezing point), and, later on, by Andrews, for temperatures 32°–16°, 16°–0°, 0°– —21°, —21°– —30°, respectively: 0·00004088, 0·00002804, 0·00002048 and 0·00001974. This is more than for nearly any other solid.

It is evident that the interior strains produced by the temperature variations must influence the strength of the ice. Hence, the physical constants of crushing and tensile strength, elasticity, etc., must vary greatly with the present

and former temperatures, even though we limit ourselves to consider only hard, solid and compact ice, neither cracked nor "rotten." Likewise do they vary with the purity of the water, its content of salts, etc. Trautwine gives the crushing strength of firm ice as 167–250 pounds per square inch. Colonel Ludlow, in his experiments in 1881, on 6–12-inch cubes, found 292–889 pounds for pure hard ice, and 222–820 pounds for inferior grades, and, on the Delaware River, 700 pounds for clear ice and 400 pounds or less for the ice near the mouth, where it is more or less disintegrated by the action of salt water, etc. Experiments of Gzowski gave 208 pounds; those of others, 310–320 pounds. The tensile strength was found by German experiments* to be 142–223 pounds per square inch. The shearing strength has been given† as 75–119 pounds per square inch.

The coefficient of elasticity has been determined in different ways. By cutting out of the ice, floating on the water, along its three sides, a long and narrow rectangular strip, and loading the extremity of this tongue with weights, Bevan found a modulus 77 x 10^7 pounds per square inch; but here the resistance of the water or the buoyancy influences the result. Trowbridge and Rae‡ removed the ice from the water and determined its elasticity by comparing the transverse vibrations of ice bars (13–13·7 inches long, 0·6–0·7 inch diameter) with those of a tuning fork, by measuring the transverse deflections of ice beams (3–7 feet long, 1·8–9 inches broad, and 1·8–4·3 inches thick), and by measuring the velocity of sound in ice. They found the latter to be 9,514 feet per second. The modulus of elasticity, as found by these experiments, was, respectively, 87 x 10^7, 102 x 10^7, 119 x 10^7, by longitudinal vibrations 122 x 10^7, and, by the rise of the deflected beam after removal of the load, 82 x 10^7; or, as an average of all, $M = 119 \times 10^7$ pounds per square inch (84 x 10^9 grams per square centimeter.)

Engineering News*, **14, 1885.
† *Nature*, **1**, 1870.
‡ *Am. Journ. of Science and Arts*, **129**, 1885.

To determine now by means of these physical constants what weight an ice sheet of a certain thickness can safely carry, we must consider separately the different cases which may occur. The ice may support a single weight in one point, or be uniformly loaded all over its surface. It may rest on the water, or this support may have been withdrawn by a lowering of the water level, such as usually takes place when the springs are frozen and the water evaporates, is absorbed by the soil, or runs off. It should also be borne in mind that the ice, according to Faraday, consists of distinct layers of different fusibility, perhaps alternately with and without a content of salts, perhaps only due to its above-mentioned intermittent growth. This naturally tends to weaken the ice, as also do air-holes formed by the confined air bursting it.

The army rules are that 2-inch ice will sustain a man or properly spaced infantry; 4-inch ice will carry a man on horseback, or cavalry, or light guns; 6-inch ice, heavy field guns, such as 80-pounders; 8-inch ice, a battery of artillery, with carriages and horses, but not over 1,000 pounds per square foot on sledges; and 10-inch ice sustains an army or an innumerable multitude. On 15-inch ice, railroad tracks are often laid and operated for months, and 2-feet-thick ice withstood the impact of a loaded passenger car, after a 60-feet fall (or, perhaps, 1,500 foot-tons), but broke under that of the locomotive and tender (or, perhaps, 3,000 foot-tons).

A theoretically correct calculation of the sustaining power of an ice sheet is hardly possible. We can establish the general equations, but merely attempt at an approximate solution of them, except in special cases.

For a plane of equal flexibility in all directions, subjected only to vertical exterior forces, Thompson and Tait* deduce the following equation for the strain z:

$$A\left(\frac{d^4z}{dx^4}+2\frac{d^4z}{dx^2dy^2}+\frac{d^4z}{dy^4}\right)=A\,\nabla^2\,\nabla^2z=Z-\frac{dM}{dx}-\frac{dL}{dy}$$

where x, y, z are the co-ordinates of a point, the $x\,y$ plane being the original unstrained plane. $Z\,dx\,dy$ is the

* "Natural Philosophy," Cambridge, 1883.

sum of the exterior forces perpendicular on the element $dx\,dy$, $M\,dx\,dy$ and $L\,dx\,dy$ the couples around the x and y axes, introduced by removing the different perpendicular forces from their points of application on the area $dx\,dy$ to its center of inertia.

For a circular strain, produced when the forces act in concentric circles, is:

$$\frac{dM}{dx} + \frac{dL}{dy} = 0$$

and hence:

$$A \bigtriangledown^2 \bigtriangledown^2 z = Z \qquad (10)$$

Considering the ice as homogeneous and isotropic (in spite of its decidedly heterogeneous and colotropic nature), we have for A, the cylindrical rigidity of flexion, the following expressions:

$$A = \tfrac{1}{12}\frac{M h^3}{1-\alpha^2} = \frac{n}{3}\frac{3k+n}{3k+4n}h^3 = \tfrac{1}{8}\frac{m\,n}{m+n}h^3 = \frac{n}{6}(1+\beta)h^3$$

where h is the thickness of the ice; M, Young's modulus of elasticity; α the ratio of linear contraction to linear elongation; k the volume-modulus; n modulus of rigidity, $m = k + \frac{4}{3}n$, and β the ratio of transversal stress to longitudinal stress corresponding to a single longitudinal strain. Substituting for α its approximately constant value, $\frac{1}{4}$ (according to Poisson) or $\frac{3}{10}$ (according to Bach), we have approximately:

$$A = 0{\cdot}090\,Mh^3$$

the coefficient ranging from 0·089 to 0·092

The strain z being a function of the radius $r = \sqrt{x^2 + y^2}$, we may transform (10) to

$$\bigtriangledown^2 \bigtriangledown^2 z = \frac{d^4 z}{dr^4} + \frac{2}{r}\frac{d^3 z}{dr^3} - \frac{1}{r^2}\frac{d^2 z}{dr^2} + \frac{1}{r^3}\frac{dz}{dr} = \frac{Z}{A} \qquad (11)$$

the integral of which contains four arbitrary constants. These are determined by the following conditions:

$$\frac{dz}{dr} = 0 \text{ for } r = 0$$

$z = 0$ and bending moment around circular arc, $G = 0$ at shore ($r = R$); shearing stress along circle of radius r:

$$2\pi r S = \int_0^r 2\pi r Z dr + P$$

for all values of r, P being any exterior vertical forces applied to single points inside the circle.

[*To be concluded.*]

CHEMICAL SECTION.

Stated Meeting of October 15, 1895.

DR. WM. C. DAY President, in the Chair.

WHAT IS BITUMEN?*

BY S. F. PECKHAM.

The exact meaning of the word "bitumen," in modern scientific literature, has been a matter of perplexity for many years. It has appeared to me impossible that any one unacquainted with the different substances included by the makers of dictionaries and cyclopædias under their descriptions and definitions, could form any clear idea of what they are. For instance, in Genesis xi, 3, a Hebrew word occurs which designates the substance used in constructing the walls of the tower of Babel. In the Septuagint this word is translated ἄσφαλτος, and in the Vulgate, "bitumen." In the Bishop's Bible of 1568, and subsequent translations into English, the word is rendered "slime." In the Douay translation of 1600 it is "bitume." In the Protestant French translation it is "bitume." In Luther's German Bible it is "thon." In removing the magnificent alabaster slabs that were used to adorn the palaces of Nineveh and Babylon, it has been discovered that the material used to cement and hold the slabs in position, was melted or natural maltha. The word "asphaltum" is said to be derived from

a, privitive, and *σφαλλο*, "I cause to slip." It therefore signifies a substance that prevents one from slipping, and was applied to the solid forms of bitumen that soften in the sun. This substance was not rare in so-called Bible lands, embracing the valley of the Euphrates, the table lands of Mesopotamia and the valley of the Jordan. It was of frequent occurrence along the shores of the Dead Sea, and was gathered and sold in the caravan trade that passed through the land of Moab and Petrea into Egypt.

During the Middle Ages, asphaltum and other forms of bitumen appear to have found but few uses, and they are but seldom mentioned. The words bitumen, asphaltum, petroleum and naphtha, appear to have been used with different meanings, and also interchangeably or synonymously; yet, the words were generally used to signify a thing that was located and defined by further description, so that the bitumen of the Dead Sea was recognised as asphaltum, or solid bitumen; that of Zante, as petroleum, etc. It is only within the last century that any serious confusion in nomenclature has appeared, and then the trouble has arisen out of commercial rather than scientific considerations. About the year 1830, the French schist oil began to assume importance. Later, the Scotch paraffine industry arose, and during the decade from 1850 to 1860 extended from Scotland to the United States, into which both the materials used and the methods of manufacture were imported. In France the materials used were properly called "the bituminous shales of Autun." In Scotland the material was called boghead coal, boghead shale and boghead mineral; it was also called Torbanite. The expense attending the importation of the boghead shale into the United States, led the Downer Kerosene Oil Company, of Boston, Mass. and Portland, Me., to make an exclusive contract for the use of the Albertite, of New Brunswick. It was called Albert coal, asphalt, pitch, etc.; and, for commercial reasons, became the subject of a very important lawsuit, in which, as experts, scientific men gave very conflicting testimony, one party claiming that the material was asphaltum, and the other that it was coal. It was finally decided that the material was not coal, and did

not belong to the Crown.[1] At about this time, a deposit occurring in West Virginia, and since known as Grahamite, and which, in appearance, is much more like splint coal than Albertite, attracted attention. There were veins of material in Cuba that were also included in the argument, Coal *vs.* Asphalt.

The word "petroleum" assumed commercial importance about the year 1860, as designating certain natural oily fluids obtained from springs or wells, and that, by refining, could be converted in large part into illuminating oils. At about the same time the solid bitumen of the island of Trinidad began to attract attention as a possible crude material for the same purpose. It was only as late as 1865 that the petroleum mania became general, and that the interest in the contest, Coal *vs.* Asphalt, was allowed to subside. At that time nearly every bitumen spring in the world became the center of developments for the production of petroleum by artesian borings. The result was the introduction into commerce of many grades of petroleum that were chiefly distinguished by differences in density and the amount of oils of certain specific gravities, and suitable for certain purposes, chiefly illumination, to be obtained from them.

The researches of Pelouze and Cahours[2] and Warren and Storer showed that the Pennsylvania petroleums examined by them consisted chiefly of paraffines and isoparaffines, the lowest member of which is marsh gas.[3] Although I had shown in 1868[4] that the Pacific Coast petroleums contained a notable percentage of nitrogen, and that they could not be made to yield illuminating oils equal in quality to those obtained from Pennsylvania petroleum; also, that asphaltum and maltha were products of the decompo-

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[1] Taylor's Statistics of Coal, Philadelphia, 1855, p. 516. Taylor's deposition before the Supreme Court at Halifax, N. S., respecting the asphaltum mine at Hillsborough, Philadelphia, 1851. On a New Variety of Asphalt. C. M. Wetherell. *Trans. Am. Philos. Soc.* (N.S.), **10**, 353.

[2] *Compt. Rend.*, **56**, 505; **57**, 62. Annales de Chimie et de Physique, (4) **1**, 5.

[3] *Mem. Am. Acad., N. S.*, **9**.

[4] *Proc. Am. Philos. Soc.* (N. S.), **10**, 445.

sition of these petroleums from natural causes; nevertheless, some of the ablest writers on petroleum continued to speak of the "petroleum springs of the Southwest," as though petroleum, maltha and asphaltum had never been defined, and millions of dollars had not been lost in attempts to obtain petroleum, as it was then known in Eastern commerce, in the valleys of Southern California, and to refine it into the best qualities of burning oils. In the fall of 1865, Drs. John Torrey and C. T. Jackson visited the center of operations on the Ojai[3] Ranche, now known as the Upper Ojai, and described as "a petroleum cascade," a hillside where a stream of maltha issued high up towards the crest of the Sulphur Mountain, and, spreading in the sun, trickled over several hundred feet of shale precipices. Any one ascending to the crest of the Sulphur Mountain, by the road leading from the Upper Ojai, can now see the same thin stream of maltha glistening in the sun, as it appeared to Messrs. Torrey and Jackson. As I saw it a year ago, there had been no apparent accumulation of material in twenty-nine years.

The wrangle over the question, whether there was any petroleum in Southern California at all, was carried on with great bitterness in 1864–5. It was really a wrangle over words more than things, for at that time, practically no petroleum worth mentioning had been found in Southern California—only just a little, enough to give a color of truth to the assertion that it was found there, thus making it possible to impose on Professor Silliman, as was done.

I have lately re-read the report that I made to the California Petroleum Company in January, 1866, and find that I then supported my statements that the bitumen of that region was maltha, and not petroleum, by references to Dana's "Mineralogy" and Dr. Ure's "Dictionary of Arts, Manufactures and Mines." These works were then well known, and had been printed many years. I thus proved that maltha was no newly discovered substance, and that, like petroleum and asphaltum, it had long been known and

[3] Ojai, pronounced O-hi.

described. These definitions are not confined to the English language, but are just as well recognised in both the French and German languages.

It therefore appears to me to be quite worthy of careful consideration that, within the last five years, a patent case should have obtained any standing at the Patent Office or before the Courts of the United States, wherein the only real point at issue was the continued misuse and misconstruction of the word bitumen and the species under it.

The history of the case was as follows: One Beardsley, who was in Southern California when I was there in 1865, patented a process for smearing paper with hot residuum from the distillation of California petroleum. As described by him, the material might also be purified asphaltum, obtained by dissolving asphaltum in petroleum, allowing the dirt to settle and distilling to a residuum the solution thus obtained. If he had called his residuum "asphalt," as others do, the patent would have been rejected; so he called it "maltha," and described it as the "solid residuum of heavy petroleum." He might just as well have called it "butter" or "guava jelly," and have defined it as he did, for no such definition of the word maltha was ever given before. This patent was allowed and issued. Then he applied for another patent on an operation that consisted in dissolving his "maltha" in carbon disulphide and applying the solution to paper. This patent was also issued, probably for the reason that the Patent Office officials did not understand the misuse of the word "maltha," and thought that a new substance was being dissolved in carbon disulphide. After various commercial evolutions, these patents became the property of the Paraffine Paint Company, on the Pacific Coast, and of the Standard Paint Company of New Jersey, in the Eastern States. They obtained their "maltha" from the Union Oil Company of California, whose works are located at Santa Paula, Ventura County, Cal. After a time, one H. J. Bird commenced the manufacture of coated paper by applying a mixture of Trinidad pitch, Carnuaba wax, wax tailings and coke pitch, neither of which was Beardsley's "maltha," or any other maltha. Meantime, the Stand-

ard Paint Company began using coke pitch, a well-known commercial product, obtained as a residue from the destructive distillation of petroleum tar. The case was brought against Bird for infringement, and has just been decided in Bird's favor, from first to last, by the full bench of the U. S. District Court, sitting at Trenton, N. J. The case was in litigation five years and ruined Bird financially.

The ground of contention was that coke pitch, being a residuum of petroleum, was Beardsley's "maltha." While the word maltha was well known to mean "mineral tar," and had had that meaning for an indefinite period, it was claimed that the action of the Patent Office in granting Beardsley's patent had "fixed the meaning of the word 'maltha' for the purpose of coating paper;" hence, Bird infringed, although he used a mixture of four substances, in neither of which was Beardsley's "maltha" as used by him. A noted expert maintained that Bird's mixture was identically the same thing as Beardsley's "maltha," because both were black, shiny, had a conchoidal fracture, and were tasteless and odorless. Since the confusion of tongues at Babel, no such confusion of names and things and mixtures of things was ever witnessed as, in this case, confounded all forms of bitumen, and all of the artificial products having properties similar to, or identical with, natural bitumens. And yet, in spite of a vigorous and able defence, it was allowed to drag along for years in an attempt to monopolise a business where invention can only apply new materials by an old process long since exhausted of patentable elements.

Again, the Bibliothèque Scientifique Internationale has just issued a posthumous work by the late eminent Swiss geologist, August Jaccard. The work is entitled "Le Petrole, l'Asphalte et le Bitume,"[6] a title in which the species is made to include the genus. The work presents the subject "au pointe de vue geologique," and for this reason many errors and defects may be overlooked from the standpoint of other branches of science. The book seeks the

[6] Le Petrole, l'Asphalte et le Bitume, par A. Jaccard, Paris. Germer Baillière et Cie, 1895.

plane of the general intelligent reader, and, despite the many grave defects that I have elsewhere pointed out, has much to recommend it; yet, in respect to the nomenclature of its principal subject, "Bitumen," it is particularly and unfortunately confused. Indeed, I do not see how a person who is not to some extent familiar with the subject, and who, therefore, reads with considerable discrimination, can clearly understand the meaning of many passages. The entire nomenclature of bitumen is used with such a confusing disregard of clear distinctions—the same word being used in different places with a different meaning—as to detract much from descriptions otherwise of great value, for there is probably nowhere to be found so complete a *resumé* of the literature extant relating to the asphaltic limestones of the upper valley of the Rhone.

It therefore seems to me desirable that the word bitumen should be once more, and clearly, defined, as the generic name of that large class of substances occurring in nature as minerals, and consisting chiefly of mixtures of compounds of carbon and hydrogen, with nitrogen, sulphur and oxygen as more rare constituents. Under this genus should be ranged, as species and sub-species, all of the natural combustible gases, naphthas, petroleums, malthas and asphaltums.

These gases include free hydrogen, carbon monoxide and all of the initial members of the different series of hydrocarbons that have been found in petroleums, together with others in each series that exist as free gases at comparatively low temperatures. These natural gases are not constant in composition, even when issuing from the same spring or well; nor are they found to be alike in composition when gases from localities yielding essentially unlike varieties of bitumen are compared. It would, therefore, be a fruitless task to attempt to give a name to natural gas as a mineral species that was in any manner derived from the chemical composition of any particular specimen of gas. It can only be described as a gaseous form of bitumen, distinguished from other natural gases by being combustible.

The word naphtha is said to be derived from the Persian

word *nafta*, and was originally used in Western Asia to designate certain fluid forms of bitumen that have an ethereal, rather than an oily consistency. In those localities, notably Asia Minor and Persia, where this class of bitumens abounds, the name "naphtha" was applied to all of the fluid forms of bitumen. From this source the word passed into Europe, where, until quite lately, it was generally used instead of petroleum. Practically, in the languages of modern Europe, the words naphtha and petroleum are synonymous, as applied to the fluid forms of bitumen.

The word petroleum, signifying rock oil, from its derivation, is properly applied to oily rather than viscous fluids. The viscous forms of bitumen, passing by insensible degrees into semi-solid or solid forms, have been designated by some French writers as "bitume glutineux," and by others as maltha. In the United States some writers describe all forms of bitumen, between natural gas and asphaltum, as petroleum, sometimes qualifying given specimens as "very light," "very heavy," "viscid," etc. This obscurity first arose in Europe, from a lack of detailed knowledge concerning the chemical constitution of fluid bitumens. De Saussure analysed the "Naphtha of Amiano," in 1817,[7] as if it were a homogeneous substance, and Boussingault, in 1837,[8] prepared his celebrated memoir upon the "Composition of Bitumens," apparently with the idea that he had separated the maltha of Bechelbronn into petroleum and asphaltum, each of which were analysed as if they also were homogeneous substances. In the United States, prior to the discovery of the Trenton limestone oils, it was assumed that there was no essential difference in petroleums, except in the proportions of the several ingredients mixed together in the oil.

True, Warren and Storer had shown, in 1865,[9] the essential unlikeness of Rangoon and Pennsylvania petroleum, and later, I, myself, showed the large amount of nitrogen in

[7] *Annales de Chim. et de Phys.* (2) **4**, 314-320.
[8] *Ibid*, (2) **64**, 141. *Jour. Frank. Inst.*, **24**, 138.
[9] *Mem. Am. Acad.*, N. S., **9**.

California oils; but Prof. J. D. Dana[10] apparently preferred to consider petroleums as rocks rather than species, and in his "System of Mineralogy," inserted Warren's series of paraffines and isoparaffines as species, although at the same time he made species of Albertite, Grahamite, etc., which we now have a right to believe, I think, only differ from liquid petroleums in the members of the paraffine and other series of hydrocarbons, which they contain. Quite lately, Maybery[11] has shown that the Trenton limestone oils contain compounds of sulphur; and Salathé and myself have discovered the esters of the pyridin and other benzole bases in California petroleums,[12] and there are very good reasons for concluding that they are constituents of all the tertiary petroleums of the Pacific Coast of both North and South America. It has been further shown that the Russian petroleums consist of hydrobenzoles,[13] while there are many reasons for believing that there are several other groups yet to be determined among European liquid bitumens. In the United States, also, there is clearly to be distinguished from all others yet investigated, a group found in the great interior valleys of the eastern slope of the Rocky Mountains, extending from Texas north into British America and the valley of the Mackenzie River.

Some of these fluid varieties of bitumen, both in Europe and America, pass, by insensible degrees and through natural causes, into maltha, which is a semi-fluid, viscous form of bitumen, known as mineral tar, and just as clearly to be distinguished in consistence from petroleum as common tar is to be distinguished from olive oil. I have found the change by which California petroleum is converted into

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[10] Dana's Mineralogy, fifth edition, 1869. I am aware that in the edition of 1892 the arrangement more nearly approaches that suggested in this paper.

[11] *Jour. Frank. Inst.*, **139,** 401.

[12] *Am. Jour. Sci.*, (3) **48,** 230.

[13] Beilstein u. Kurbatow, *Ber. d. Deut. Chem. Ges.*, **13,** 1818; Schützenberger et Jonine. *Bul. Soc. Chim.*, Paris, 1880, p. 673. Since the above was written, a memoir by Wanklyn and Cooper has appeared in the *Chem. News.*, **72,** 7, in which it is shown that a new group, called by them "keroses," exists in Russian kerosene.

maltha to be due to two causes, viz.: evaporation and indirect oxidation.[14] By this latter term, I mean, not that oxygen becomes to any extent a component of the maltha, if at all, but that by oxidation and removal of hydrogen the molecules are condensed as the proportion of carbon increases. Prof. Henry Wurtz would have us believe that this change is due to polymerisation.[15] I cannot interpret the results of my experiments as indicating such a result alone. When air, ozone, or chlorine, is passed through the paraffine petroleums, they are condensed by evaporation to a residue resembling vaseline. When California petroleums are treated in the same manner, they are condensed by decomposition into, first, maltha, and then asphaltum. Chlorine will effect this change just as readily as ozone.[16] Destructive distillation will also effect the same or a similar change, the residue being either an asphaltic residuum, or coke, and the distillate a hydrocarbon richer in hydrogen than the original bitumen. The natural malthas contain both water and air in mechanical admixture.

When the solid forms of bitumen are reached, the want of clear distinctions becomes still more pronounced. The work of M. Jaccard affords an illustration of the lack of clear ideas expressed in clear language, in which some authors indulge. The late Dr. T. Sterry Hunt, as long ago as 1863,[17] separated pyrobituminous from bituminous minerals. This important consideration, while not wholly disregarded by M. Jaccard and other authors, does not appear to be fully appreciated by him. The fundamental principle underlying the use of this word exists in the fact that "pyrobituminous" coals, schists and shales yield, on being heated to destructive distillation, products that resemble bitumens. Why this clearly scientific, wholly reasonable and very convenient basis of classification has not been made the foundation upon which all scientific dis-

[14] *Am. Jour. Sci.*, (3) **48**, 254.
[15] *Engineering and Mining Journal*, 1889, 1890, 1891.
[16] *Proc. Am. Philos. Soc.*, **10**, 445.
[17] *Am. Jour. Sci.*, (2) **35**, 157. Chemical and Geological Essays. J. R. Osgood & Co., Boston, 1875.

cussions relating to bitumens proceed, whether from the point of view of geology or any other point of view, it is difficult to explain. Yet, until this distinction is fully recognised, writers will continue to mix up bituminous coals, schists of Autun and Mansfeld, boghead mineral, etc., with all sorts of bitumens, as M. Jaccard has done, to the infinite confusion of the discussion of bitumens. These coals, schists and shales are nearly as insoluble in the solvents of bitumen, viz.: ethyl ether, chloroform, benzole, etc., as they are in distilled water; hence, Dr. Hunt made the action of these solvents exclusive of the two classes of substances. All true bitumens are miscible with, or almost wholly soluble in, chloroform, a test that clearly separates them from pyrobituminous minerals. So-called "asphaltic coals" are not coals at all, but are simply geologically old asphaltums.

In whatever manner bitumens may be classified, it is apparent from the outset that there are a large number of minerals, consisting in part of true bitumens, that are, strictly speaking, rocks. To this class of substances belong the bituminous sandstones and limestones of the upper valley of the Rhone, the Limmer and Ragusa rocks, the Niagara limestone of Chicago, the bituminous limestones of Utah, the Turrellite of Texas, the sandstones of Kentucky, the Indian Territory and the Athabasca River and California. These are found as beds of sedimentary or crystalline rock, often of immense extent and thickness, impregnated with bitumen of varying consistency and quality, sometimes nearly fluid, but never solid, after being separated from the rock. In some instances the bitumen appears to be convertible into asphaltum, and in others not. The French writers have called these rocks "asphalte," but unfortunately they have also called asphaltum by the same name, as if the things were identical and the words synonymous. Among English writers no uniform custom prevails, but German authors use generally the French word. I think it would promote clearness of expression if this word "asphalte" were uniformly introduced into all modern languages to designate these bituminous rocks, with the quali-

fying words, siliceous, calcareous or argillaceous, added as required.[18]

The so-called Trinidad pitch, as it is found in and around the lake, is a unique mixture of bitumen, water, mineral and vegetable matter, the latter usually determined as "organic matter, not bitumen," and the whole inflated with gas. When removed from the deposit, the water rapidly dries out, the gas escapes, the mass becomes brittle and changes from a brown to a blue-black color, acquiring a sticky consistency as it loses water. At a rough estimate, less than 25 per cent. of the mass of the natural cheese pitch is bitumen; it is, therefore, quite improperly called the largest deposit of bitumen in the world. I think that the Trinidad pitch, so-called, is properly to be considered a mineral species, and I suggest for it the name "Parianite," in reference to the formation in which the celebrated lake occurs.

The words natural gas, naphtha, petroleum, maltha, asphaltum and asphalte, are not names of things, but words which indicate accidents of occurrence, to which any species of bitumen may be subject. When a true system of classification of the species and sub-species under bitumen has been reached, it will be found that a species may occur in nature in any or all of the several conditions, from natural gas to asphalte. A true system, therefore, must name and classify the bitumens themselves. As an illustration of my meaning, I would suggest that the constitution of Pennsylvania petroleum, having been first shown by C. M. Warren to consist in a mixture of paraffines, isoparaffines, etc., this species of bitumen embracing the natural gas and petro-

[18] Last December, Miss Laura A. Linton published a paper in the *Journal of the American Chemical Society*, upon the "Technical Analysis of Asphaltum." In this paper the words asphalt and asphaltum were used interchangeably. The paper was reprinted in the London *Chemical News*, and the careful editor added the letter e to asphalt wherever it occurred. I have looked through all of the English and American dictionaries, from Samuel Johnson's down, and through all of the cyclopædias printed in English, to which I have access, including the ninth edition of the Britannica, and I cannot find the word asphalte anywhere as an equivalent for asphalt. Asphalte is not an English word.

leum of western Pennsylvania, eastern Ohio and West Virginia, may properly be named "Warrenite." As Prof. C. F. Maybery has first clearly pointed out the characteristics of the Trenton limestone oils by means of his researches upon the sulphur compounds contained in them, I would suggest for this species of bitumen the name "Mayberyite." As the California bitumens containing the esters of pyridin, etc., are largely found in Ventura County, I would suggest for them the name "Venturäite."

I am aware that these suggestions are based upon data very inadequate for the purpose of complete classification, yet I contend it is a classification that will classify things and not names, and, in time, may be made sufficiently complete for the purposes of mineralogy as well as technology.

The old terms will still have their places and uses by which to indicate the physical conditions under which these different mineral species are found. As an illustration, I will suggest that a description of "Warrenite" would include the statement that it is found as natural gas, naphtha, petroleum, etc.; that it consists of paraffines, isoparaffines, olefines, a trace of benzoles, etc. Analyses might be given from the researches of Warren and Storer, Pelouze and Cahours, Ashburner, etc. It occurs along the western slope of the Allegheny Mountains, from New York to southern Kentucky, in natural springs and artesian borings.

"Mayberyite" is found as natural gas, petroleum and maltha; it consists of paraffines (?), isoparaffines (?), olefines (?), esters of the pyridin bases (?), and Maybery's sulphur compounds. Give analytical references. It occurs in the petroleum region of Canada, in northwestern Ohio and Indiana, and southward.[19]

"Venturäite" is found as natural gas, petroleum, maltha and asphaltum; consists of hydrobenzoles (?) esters of pyridin bases, etc. It occurs throughout Southern California, as petroleum in artesian borings; as maltha saturating

[19] In one instance, I obtained a qualitative reaction for the pyridin bases in a sample of commercial "lima tar." I have not yet been able to verify their presence in other and authentic samples.

sand at Las Conchas, in enormous springs on the Ojai, and in many other localities; as asphaltum, in veins of immense extent, probably the largest in the world, at Asphalto, Kern County, Cal.; also at La Patera, Santa Barbara County, in the same State.

It goes without saying that there has been no scientific examination of any solid bitumen that is worth mentioning, consequently any attempts at specific description like those given above are like a skimmer, consisting chiefly of vacant spaces. Nevertheless, shall we go on multiplying words about the "bitumen of the Dead Sea," "Trinidad pitch," "California asphalt," etc., or shall we begin to learn by first discovering how difficult it is to answer the question: "What is Bitumen?" Let those who think they can answer it first read M. Jaccard's book.

UNIVERSITY OF MICHIGAN,
ANN ARBOR, MICH., August 24, 1895.

ON THE TECHNICAL ANALYSIS OF ASPHALTS.

BY SAMUEL P. SADTLER, PH.D.

In an article published in the *Journal of the American Chemical Society*, for December, 1894, Miss Laura A. Linton gave, under the above heading, a most valuable discussion of the present methods of asphalt analysis. As she well says, the "petrolene" of the writers on asphalt "is nothing but a name that covers a great variety of substances, radically unlike, that exist in different forms of bitumen, and are only related in this instance as being held in solution by a certain limited number of menstrua, and which include the whole list of paraffines and isoparaffines, the olefines, the benzenes and additive benzenes, with many other less abundant and well-known substances." Similarly, "in a general way, it may be said that asphaltene is that portion of the different forms of bitumen that is soluble in carbon disulphide, chloroform, benzene, and a few other less known

* Read at the meeting of the Chemical Section, September 17, 1895.

liquids, and is not soluble in the menstrua that dissolve petrolene."

Miss Linton recommends, therefore, as a process for uniform treatment of asphalts, to digest them first with petroleum ether, decanting the liquid upon a filter, and ultimately the undissolved bitumen also. After getting the weight of the filter and contents, it is treated with boiling turpentine, with which it is digested for some time, the funnel being covered. After repeating this treatment until the filtrate becomes colorless, chloroform is taken to finish the extraction of the asphaltene. After another weighing of the filter and its contents, it is to be burned in a platinum crucible, in order to determine the organic non-bitumen and ash.

This process of Miss Linton, while giving results that are comparable, becomes very tedious in practice, besides requiring the use of three solvents, of which one (the boiling turpentine) is unsatisfactory because of its resinous and sticky tendency.

I have sought, therefore, to find a more expeditious process without sacrificing completeness of extraction, or allowing the results to fail in comparability.

With this in view, I have chosen a form of apparatus in which a continuous extraction can be carried out without requiring the transference of the weighed sample from one vessel to the other. The solvents chosen are definite compounds of fixed boiling point, which can always be had pure and subject to no alteration; the extraction goes on continuously at the boiling point of the solvent; and the solvents are recovered for use again.

The solvents chosen are acetone, as a substitute for the petroleum ether, for the extraction of the petrolene; and chloroform, for the extraction of the asphaltene. Both acetone and chloroform can be had perfectly pure, and are not alterable, so that they possess distinct advantages over petroleum ether and carbon disulphide.

The analysis is carried out as follows:

An asbestos filter is made in a weighed Gooch crucible, and dried. About 10 grams of fine white sand, previously

ignited and cooled, is added, and a piece of stout platinum wire, about 3 inches long, is placed in the crucible, and the whole dried to a constant weight at 100° C.

Then 1 to 2 grams of the asphalt, in fine powder if a solid, are added, gently mixed with the upper portion of the sand layer with the aid of the platinum wire, care being taken not to disturb the asbestos filter below. The weight of the whole is accurately taken, inclusive of the wire and the crucible, and its contents are then dried at 100° C. to a constant weight, either in an air bath or water oven, cooled in a desiccator and weighed. If the sample be a maltha (liquid bitumen), it is gently mixed with the sand layer, after slightly softening it with the aid of the drying oven. The loss at 100° C. is calculated and called "moisture and loss at 100° C." The crucible and its contents are then placed in a continuous extraction apparatus, formed by placing a small percolator within a larger one, the inner one being held in position by a perforated cork. The crucible having been placed in the inner percolator, the outer one is connected with a flask containing the solvent, and with an upright condenser. The flask is heated either on a sand bath or a water bath, the former being preferable, since when once regulated it needs no attention or renewal as does the water bath. The extraction with acetone, which is first undertaken, is continued until the loss on extracting for two hours is not more than 1 or 2 milligrams. The loss of weight after this extraction, as compared with the weight on starting the extraction, is calculated and called "petrolene." The extraction is then continued in the same manner with chloroform, and the final loss is the "total bitumen." The time necessary to effect a thorough extraction varies greatly with the different asphalts, but will not amount to more than twelve hours for the acetone and eight hours for the chloroform extraction. The loss in weight should be taken first after four hours, and then every two hours until the extraction is complete, the crucible and contents being dried at 100° C., and cooled in a desiccator each time. The residue in the crucible then represents the organic non-bitumen and mineral matter. It is ignited, after placing the

cap on the bottom of the crucible, and the loss calculated as "organic non-bitumen," while the remainder is the "mineral matter" or "ash."

Duplicate analyses of two well-known varieties of asphaltum were made to test the method:

REFINED TRINIDAD ASPHALT.

	I.	*II.*
Petrolene	46·40	46·41
Asphaltene	15·14	15·20
Organic non-bitumen	3·02	2·95
Mineral matter	35·44	35·44

REFINED BERMUDEZ ASPHALT.

	I.	*II.*
Petrolene	66·47	66·45
Asphaltene	29·66	29·71
Organic non-bitumen	1·76	1·73
Mineral matter	2·11	2·11

As an example of a maltha, or liquid bitumen, examined by this method, may be given the following analysis of

ALCATRAZ LIQUID ASPHALT.

	Per Cent.
Petrolene	89·21
Asphaltene	9·39
Organic non-bitumen	trace.
Mineral matter	1·40

In publishing this note I wish to acknowledge my indebtedness to Mr. H. Blount Hunter, my assistant, for the very intelligent and skilful way in which he has carried out most of the experimental work.

PHILADELPHIA, September 17, 1895.

NOTES AND COMMENTS.*

CASTNER'S ELECTROLYTIC METHOD FOR PRODUCING CHLORINE AND ALKALI.

At the Fourteenth Annual Meeting of the Society of Chemical Industry, lately held at Leeds, England, the president, Prof. T. E. Thorpe, in his address, made the following allusion to the interesting process of Mr. Hamilton Castner for the electrolytic decomposition of alkaline chlorides, several references to which have lately appeared in the *Journal*, viz.:

* From the Secretary's monthly reports.

"The application of electrical energy to the decomposition of alkaline chlorides, either for the production of chlorine, or alkali, or of both products, has been made the subject of many patents. The great majority of these processes have been stillborn, and even of those which were stimulated into vitality, the existence has been short and feeble. With a sounder knowledge of the conditions under which alone success is possible, the problem is once more attracting the attention of technologists, and the chemical world is watching, with great interest, the results of two or three electrolytic processes which are now being worked out on the large scale. One of these is the invention of our member, Mr. Hamilton Castner, and has been in practically continuous operation for nearly twelve months, at the Aluminium Company's works, at Oldbury. In Mr. Castner's process, the difficulties connected with the use of diaphragms, and the liability to recombination of the products to form hypochlorite, are obviated, whereby the destruction of the electrodes is prevented, and a much higher electrical efficiency is obtained. I am indebted to Mr. Castner for the following account of the method: The essential feature of the process is the employment of a moving body of mercury, which completely separates the products of electrolysis, and, by its movement, takes the place of a diaphragm, the sodium amalgam formed being decomposed as it is formed. The cell, which is divided into three compartments, is capable of being continuously rocked or tilted, so as to cause the mercury to flow from side to side. The two outside compartments contain the alkaline chloride solution and the carbon anodes, while the middle compartment contains an iron cathode and the caustic solution. The solution of the chloride is continuously circulating through the outside compartments, wherein it is being electrolysed, and then returns to saturators, where it is re-charged with salt. The electric current, traversing the salt solution, liberates chlorine and forms sodium amalgam. The chlorine escapes from each cell, through an aperture, into a collecting main, while the sodium amalgam, by the continuous back-and-forward tilting of the cell, passes to the center compartment, where it acts as an anode during the passage of the current, the sodium going into solution as caustic. A regulated quantity of water is admitted hourly to the center compartment of each cell, causing the pure solution of caustic to overflow through a discharge pipe into a large collecting pipe connecting all the cells. The cells are electrically connected in series, and are capable of being cut out or put into operation at will."

FORCE REQUIRED IN DRIVING AND PULLING CUT WIRE NAILS*.

By Professor R. C. Carpenter.

The experiments described show the force required to drive and start the nails, and also the relative work in each case. To obtain some figures which would give not only the maximum force, but also the work required both for

* Abstract of paper read at the Detroit Meeting of the American Society of Mechanical Engineers June, 1895.

driving and pulling various nails, the writer had the following experiments conducted in the laboratory of Sibley College. Nails of various kinds were forced into a piece of Southern pine, which was as nearly homogeneous as was possible to obtain, by one of the heads of a testing machine, and the amount required at the end of each one-quarter inch of penetration was noted. The nails were driven within about one-quarter inch of their full length in each case.

In pulling, they were drawn out by a species of forceps attached to the testing machine, the force required being noted at each one-quarter inch. Diagrams were then drawn corresponding to the force exerted and the depth of penetration, the integration of these diagrams giving the total work either for driving or for drawing. Experiments were made on ten nails of each kind, and the averages taken to represent the work of any particular class.

The general summary of the experiments is given in the following table, from which it will be noted: (1) That very much more force is required to drive

SUMMARY OF EXPERIMENTS IN DRIVING AND PULLING NAILS IN SOUTHERN PINE WOOD.

No. of Nail.	Kind of Nail.	Number to One Pound.	Depth of Penetration. Inches.	Maximum Load to Drive. Pounds.	Max. Load to Start in Pulling. Pounds.	Work in Inch-Pounds.		Maximum Weight Per Pound of Nails in Tons.		Work in Foot-Pounds Per Pound of Nails.		Relative Efficiency.
						To Drive.	To Pull.	To Drive.	To Start.	To Drive.	To Pull.	
20d	Cut	23	3½	819·6	920·8	1,522·85	477·6	9·34	11·6	2,915	915·0	31·6
20d	Wire . . .	34	3½	376·0	318·0	864·6	472·8	6·41	5·42	2,450	1,335·0	54·5
10d	Cut	70	3	341·6	316·8	585·25	200·85	11·9	12·5	3,410	1,215·0	35·5
10d	Wire . . .	105	3	232·4	213·6	435·65	220·2	12·2	11·4	3,830	1,940·0	50·7
10d	Cut	—	3	483·0	518·0	699·75	284·7	—	—	—	—	41·0
	Sharpened:											
8d	Cut	88	2¾	312·4	328·4	419·1	140·1	13·7	14·5	3,038	1,019·0	33·5
8d	Wire . . .	132	2¾	198·8	167·2	278·6	104·6	13·2	11·1	3,340	1,255·0	37·5
6d	Cut	168	1¾	221·2	155·6	274·3	64·5	18·7	13·3	3,830	904·5	23·5
6d	Wire . . .	252	1¾	134·6	87·6	165·2	62·75	16·9	15·0	3,480	1,320·0	38·0

a cut nail a given distance than a wire nail. (2) That more force is required to start a cut nail generally than to drive it, and that it invariably starts much harder than a wire nail. (3) The work in inch-pounds per nail required in driving cut nails is much more than that in driving wire nails. (4) The work in inch-pounds in pulling cut nails is about equal, sometimes less and sometimes greater, per nail, than that for pulling wire nails. (5) The maximum force per pound in driving or starting wire nails is more nearly equal to that of the cut nails than when estimated on the basis of that of a single nail, but it is still less. (6) The work, in foot-pounds, per pound of wire nails, re-

quired for driving is less than that required for the cut nail, and that for pulling is considerably more. (7) The relative efficiency which is here considered as the ratio of the work of pulling to that of driving, is much higher for the wire nail than for the cut nail.

In making experiments it was noticed that the cut nail bruised and broke the fibers of the wood, principally at the end of the nail, whereas, the wire nail simply crowded them apart, and probably did not move them much beyond the point from which they would return by elastic force, and hence the nail would be grasped much stronger per unit of area of surface by the wood. Presenting less surface there would be, however, less resistance to starting.

To see what the effect of change of form would be, a number of ten-penny cut nails were sharpened on the point by grinding to an angle of about 30°, so that the fibers in advance of the nail would be thrust aside, and not bruised and broken. This served to increase the holding power over the cut nail of ordinary shape about fifty per cent. in starting force and about thirty per cent. in work of resistance to pulling.

The good result produced in sharpening the end is shown by some experiments made some years ago in the Sibley laboratories on the holding power of ordinary railroad spikes, as compared with a Walcott spike, which differed from the ordinary railroad spike in having a sharp end, and also in having two longitudinal grooves stamped into one side.

Tables are presented which show the resistance to pulling when driven five inches; the weight required to drive twenty-penny cut nails for each one-quarter inch of length; weight required to pull twenty-penny cut nails each one-quarter inch in depth; the same in regard to wire nails, and also table showing driving and pulling force for cut and wire nails of ten-, eight-and six-penny size.

RAILROADS OF THE UNITED STATES IN 1894.

The Engineering and Mining Journal gives the following very satisfactory abstract of the condition and operations of the railroads of the United States from the Seventh Statistical Report of the Interstate Commerce Commission for the year ending June 30, 1894:

In the introduction to the report especial attention is called to the peculiar conditions affecting the operation of railways during the year covered by the report. (1) The report covers the last four months of the Columbian Exposition, during which time there was an increased passenger traffic. (2) It covers a period of widespread and unprecedented business depression. (3) At the close of the year, 192 roads, operating upwards of 42,000 miles of line and representing about one-fourth of the total railway capitalization, were in the hands of receivers. The effect of these conditions is apparent in nearly all of the figures presented.

The total railway mileage in the United States on June 30, 1894, was 178,708, an increase during the year of 2,247 miles. The increase during the previous year was 4,897 miles. The total number of railway employés was 779,608, a decrease, as compared with the number on June 30, 1893, of 93,994, or 10 76 per cent.

The total amount of reported railway capital on June 30, 1894, was $10,796,473,813, or $62,951 per mile of line. This is an increase in the amount outstanding during the year of $290,238,403. The amount of capital stock was $4,834,075,659, of which $4,103,584,166 was common stock, and $730,491,493 was preferred stock. The funded debt was $5,356,583,019, classified as follows: Bonds, $4,593,931,754; miscellaneous obligations, $456,277,380; income bonds, $242,403,681, and equipment trust obligations, $63,970,204. The amount of current liabilities was $605,815,135. The amount of railway securities held by railway companies as an investment was $1,544,058,670, a decrease during the year of $18,963,563.

The amount of stock paying no dividend was $3,066,150,094, or 63·43 per cent. of the total amount. Of the stock paying dividends, 4·31 per cent. of the total stock paid from 4 to 5 per cent.; 10·12 per cent. paid from 5 to 6 per cent.; 5·12 per cent. paid from 6 to 7 per cent., and 5·42 per cent. paid from 7 to 8 per cent. The total amount of dividends was $95,575,976, or an average rate on the dividend-paying stock of 5·41 per cent. The amount of bonds paying no interest was $650,573,789, or 14·17 per cent. The amount of miscellaneous obligations paying no interest was $53,426,264, or 11·71 per cent., and the amount of income bonds paying no interest was $210,757,554 or 86·94 per cent.

The gross earnings of the railways for the year ending June 30, 1894, were $1,073,361,797, a decrease as compared with the previous year of $147,390,077, or 12·07 per cent. Passenger revenue decreased $16,142,258, or 5·35 per cent, and the revenue from freight traffic decreased $129,562,948, or 15·63 per cent. The amount of operating expenses was $731,414,322, a decrease of $96,506,977, or 11·66 per cent. The largest decrease was in the operating expenses assigned to maintenance of way and structures and to maintenance of equipment. The net earnings were $341,947,475, a decrease of $50,883,100 as compared with the previous year. The income derived from sources outside of operations was $142,816,805. The amount of fixed charges and other deductions from income was $429,008,310, leaving a net income of $55,755,970 available for dividends, a decrease as compared with the previous year of nearly 50 per cent. The amount of dividends paid was $95,575,976, a decrease of only $5,353,909 from the amount paid the previous year. The fact that nearly the normal amount of dividends was paid notwithstanding the great decrease in income available for them, and that the payment of the amount stated entailed a deficit from the operations of the year of $45,912,044, is suggestive. The revenue derived from the carrying of passengers was $285,349,558, or 26·58 per cent. of gross earnings, and the revenue derived from freight traffic was $699,490,913, or 65·16 per cent. of gross earnings.

During the year 1,823 railway employés were killed and 23,422 were injured, as compared with 2,727 killed and 31,729 injured in 1893. To show the ratio of casualty, it may be stated that one employé was killed out of every 428 in service, and one injured out of every thirty-three employed. The trainmen perform the most dangerous service, one out of

every 156 employed having been killed and one out of every twelve having been injured.

The ratio of casualty to passengers is in striking contrast to that of railway employés, one passenger having been killed out of each 1,912,618 carried, or for each 44,103,228 miles travelled, and one injured out of each 204,248 carried, or for each 4,709,771 miles travelled.

According to the 1895 edition of "Poor's Manual of Railroads," just published, the length of track laid in the United States up to December 31, 1894, was 179,279·34 miles. The net increase of mileage of all railroads in the United States in the calendar year 1894 was 1,821·38 miles. There was a total revenue train mileage in operation in 1894 of 881,332,712 miles, including passenger, freight and elevated railroad traffic. Compared with 1893, the gross earnings of the railroads decreased in 1894 $142,313,275, to which decrease the elevated railroads contributed only $1,315,290. The total liabilities of the railroad companies at the close of 1894 were $11,565,600,207, and the total assets $11,924,450,884, leaving an excess of assets over liabilities of $358,850,677.

DETERMINING THE QUALITY OF BRASS BY COLOR.

So long as anything has been known as to the nature of the alloy of copper and zinc, certain distinctive colors have been associated with certain classes of brass. No attempt, however, has hitherto been made to distinguish the minute gradations of shade corresponding to slight modifications in the percentage composition, or to apply these variations systematically to any practical use. At a recent meeting of the British Society of Chemical Industry, Walter G. McMillan read a paper quoted in a London plumbing journal, in which he described a system which he devised about a year ago, by means of which it is possible to form an approximately accurate opinion of the composition of any given sample of brass, merely by observing the color of drillings or shavings prepared from the sample. In order to effect this satisfactorily it is necessary to have at hand a set of sealed glass tubes containing drillings of brass of known composition. With these standard drillings the drillings of any sample whose composition is desired to be known are compared. When the color of the sample is matched with that of a standard tube it is warrantable to assume that the known composition of the standard is approximately that of the sample. In this way the quality of any sample of brass may be rapidly determined by any buyer or user who is not color-blind and is possessed of average intelligence, thus avoiding the expense, labor and expenditure of time which would be occasioned if the sample had to be analysed.—*Iron Age.*

BRITISH MINERAL STATISTICS FOR 1894.

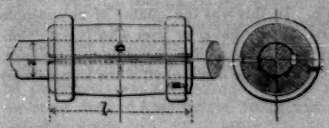
For comparison with the figures of the Mineral Statistics of the United States for the same period, published in the impression of the *Journal* for July, 1895, the following official data are from the annual *Mineral Statistics* of the United Kingdom for the year 1894: The production of coal in the United Kingdom

last year was 188,277,525 gross tons, against 164,325,795 tons in 1893, an increase of 23,951,730 tons. The year 1893 was, however, a year of serious strikes in the coal trade, from which 1894 was measurably exempt. The production of 1894 was the largest ever attained in the history of the British coal industry. The production of iron ore in 1894 was 12,367,308 tons, against 11,203,476 tons in 1893, an increase of 1,163,832 tons. The imports of iron ore into the United Kingdom in 1894 amounted to 4,413,652 gross tons, against 4,065,864 tons in 1893, an increase of 347,788 tons. The production of pig iron in the United Kingdom in 1894 was 7,427,342 tons, against 6,976,990 tons in 1893, an increase of 450,352 tons. The production of tin ore in 1894 was 12,910 tons, against 13,689 tons in 1893, a decrease of 779 tons. The production of block tin from domestic tin ore in 1894 was 8,327 tons, against 8,838 tons in 1893, a decrease of 511 tons. The imports of tin ore in 1894 amounted to 4,437 gross tons, against 3,040 tons in 1893, an increase of 1,397 tons. The imports of block tin in 1894 amounted to 39,147 tons, against 33,558 tons in 1893, an increase of 5,589 tons. It may be useful for those interested in the American tin plate industry to learn that the United Kingdom imports more than four times as much block tin as it produces, and if allowance be made for the block tin smelted from imported tin ore, its importations of block tin from other countries are five times as large as the domestic production.

A SIMPLE AND EFFECTIVE SHAFT COUPLING.

Mr. John H. Cooper contributes to *Power and Transmission* an interesting mechanical item, of which we make the following abstract:

This coupling, shown by accompanying cut, is a plain sleeve of cast iron, made slightly conical both ways from its center, and upon which two wrought-iron bands are driven. It is cut through and through on one side to the bore, which permits a slight opening and closing of the same, within the elastic limit of the metal. The key-way is cut parallel the whole length of the coupling, and directly opposite to the line of separation; it is done at the one setting in the planer. The bands are preferably of wrought iron, bored to fit the cone of the coupling, and are driven on by a "set" to the desired tightness, sufficiently to firmly close the body of the coupling upon the ends of the shafts to be joined.



It consists of a single piece of metal, without flanges, and requires no bolts to hold it together; nor has it any projecting parts, liable to catch belts or ropes or the loose garments of men.

It closes with a holding grip (being bored slightly smaller) upon each end of the coupled shafts, and may readily be removed and replaced without disturbing shafts, or bearing, or vitiating its fit or finish. It may be made very light or very heavy for any required service; short or long, according to space at disposal for it; may be

polished or not, according to taste or the style of the shafting, pulleys and hangers.

It requires neither special tools nor superior workmanship to make, to put it on or to take it off the shafts. It can be duplicated to any extent with certainty of an effective fit, which is more than can be said of the bolted "plate" coupling. It goes to its place without specially fitted keys for driving, as required by the "plate" and other solid couplings; it adapts itself to slight differences of shaft diameter, such as are incidental to shaft turning, and it "stays put" when the bands are driven "home."

The proportions for ordinary service may be summed up in the following: The total length and the middle diameter of the body, the width and the thickness of the bands are to be made, respectively: four times; double; one-half and one-fourth of the nominal diameter of the shaft.

With careful moulding and lathe centering, and for ordinary painted work, the coupling body need not be turned on the outside or ends, and for this style the bands may be cast of steel or best malleable iron, and used without turning or polish; but may be of wrought iron, turned or not, according to character of forging and exactness of finish wanted. In this decision, the only machine work necessary would be the boring, which, for any and every style of coupling, must be truly cylindrical and straight, and which, for this coupling, may be a trifle smaller than the shafts.

The cut through one side may be of the same width as the key-way, for economy of tools and time, but there is no objection to the least width that will permit grip upon the shafts. The key-way opposite may be made to suit the proportions already adopted by any shop. The intention here is to use parallel keys of uniform square section.

Some styles of couplings rust fast, and are, in consequence, difficult of removal. There is no such trouble with these; a wedge driven into the separation, after the bands are off, will free them at once.

Mr. Cooper, speaking of this coupling, says:

"I have applied these couplings where other first-class types have failed not without some misgivings, however, until full trial was past, when they proved themselves of superior holding ability.

"The philosophy of their firmness in holding is simple enough when one considers the efficiency of a band of wrought iron in direct tension. The simplest remedy for a broken thing is to shrink a wrought iron band upon it, which, in many cases, makes it stronger than it was before. This is readily admitted on the fact of the low tensile strength of cast iron, as compared with that of wrought iron, especially when the latter is under better conditions for resisting rupture.

"I began making these couplings about thirty years ago, and have since used them in every place that offered, and always with good results. Millwrights like them because they are so easy to apply and remove. First-class tool and shafting builders are making them now, which I regard as ample proof that every required dependence can be placed upon them. They have been made to couple two sizes of shafts, also cut apart longitudinally into two equal halves. In unusual cases I have made them with bolts for draw-

ing the bands on, holding them in position, and then with inside nuts on the bolts, to be used for forcing the bands asunder when uncoupling became necessary. In close quarters, where the hammer cannot be used, the bolting method answers well."

BOOK NOTICES.

Steam and the Marine Steam Engine. By John Yeo, Fleet Engineer, Royal Navy, etc. London and New York: Macmillan & Co. (Price $2.50.)

The author, being instructor in steam and marine engineering at the British Naval College, gives, in the above work, a condensed abstract of the course of instruction at this renowned institution. Treating chiefly of matters pertaining to naval construction, it is most valuable to naval officers and engineers, but should also be useful to those interested in the mercantile marine and students of engineering generally. To treat so large a subject within so small a volume is by no means easy, and the author must be complimented upon the manner in which he has given the history of the subject and the scientific principles of the same, in brief but concise outlines, at the same time describing and illustrating a number of important detail's. Without wasting any time and space on antiquated styles and constructions, he proceeds at once to give general outline sketches and very neat detail plans of the most modern styles of engines and boilers now in use on naval vessels, not omitting the most important forms of water tube boilers now in use; also paying some attention to valve gear, indicator diagrams, etc.

In the chapters devoted to heat, principles, properties and efficiency of steam, these important matters are treated with a simplicity and absence of complicated formulas which should make them plain to the ordinary engineer, and will even be welcome to many designers and constructors, who, in the routine of their practical career, may have grown a little rusty in the higher mathematics.

The chapters on boiler preservation, combustion of fuel, etc. contain valuable information which is generally not found in books, and the chapter treating on propulsion and propellers (although based on the antiquated and only approximate theory, that the power varies as the cube of the speed) shows clearly, by description and a number of examples, the relations between power, speed, consumption, etc. J. H.

Elementary Lessons in Steam Machinery and the Marine Steam Engine. By Staff Engineer J. Langmaid and Engineer H. Gaisford. Macmillan & Co., London and New York. (Price, $2.)

This little book was prepared for the Naval Cadets on H. M. S. *Britannia*, and forms an admirable course of preparatory instruction, laying a sound basis in the elements of construction and mechanism, on which to build up, by a more thorough study, combined with practical experience on board ship

and workshop duty ashore, a thorough knowledge of marine engine construction and management.

Beginning with a chapter on exact measurements, also giving terms of forces acting on the materials used in construction, the latter and their treatment are next described, followed by details of machinery and boilers, their principles, construction and appendages. One very useful illustration shows a cylinder and valve-chest, with movable piston and valve, enabling the student to follow the movements and relative positions of these important parts at every point. A complete description and illustration of the engines of the cruisers *Sappho* and *Scylla* is given, and the book closes with a short description of a battleship.

The book is very well printed, on excellent paper, the engravings being on separate pages, and well executed.

This work may also be useful and interesting to non-professional readers, who wish to gain a general knowledge on the subject. J. H.

Encyclopédie Scientifique des Aide-Mémoire. Sous la direction de M. Leauté, Membre de l'Institut (Section de l'Ingénieurs). Paris: Gauthier-Villars et Fils et G. Masson.

The following additional volumes of this technical series have appeared since our last notice. For general description of the scope and objects of this publication, the reader is referred to earlier notices. All volumes are uniform in size (small 8vo), and each is an independent treatise on the subject to which it relates. W.

Hennebert. Lieutenant-Colonel du Génie, ancien Professeur à l'École militaire de Saint-Cyr, etc.—*Bouches à feu.*

Caspari, E. Ingénieur hydrographe de la Marine.—*Les chronomètres de marine.*

Dariès, G. Conducteur des Ponts et Chaussées, attaché à la Direction des Eaux de Paris. *Cubature des terrasses et mouvement des terres.*

Hennebert. Lieutenant-Colonel du Génie, ancien Elève de l'École Polytechnique.—*Torpilles sèches.*

Vallier. Chef d'Escadron d'Artillerie, Correspondant de l'Institut.—*La Balistique extérieure.*

Sidersky, D. Ingénieur chimiste.—Polarisation et saccharimétrie.

A Manual of Marine Engineering. By A. E. Seaton. Twelfth edition. London: Charles Griffin & Co., Lim. New York: D. Van Nostrand Co. (Price, $6.)

Mr. Seaton's book, when first published, was at once accepted as a standard work, and its successive editions have confirmed its claim to pre-eminence by keeping abreast of the latest developments in marine propulsion, extraordinary as they have been during the last twenty-five years. When we

consider that pressures in marine boilers have increased from 60 to 200 pounds, and piston speeds from 400 to 1,000 feet per minute, reducing coal consumption from 3 to 1¼ pounds per horse-power per hour, and increasing the horse-power attainable from a square foot of grate from 5 to 20, we can realise the enormous gain in economy of fuel, in space and weight for machinery, which enables our ocean greyhounds to cross the Atlantic at a speed of 22 knots per hour. In naval construction these developments have resulted in an increase of offensive and defensive power, which is at once apparent by comparing the battleship of to-day with the first ironclads built thirty years ago.

To introduce and develop these changes required constant advance in design, materials, methods, etc., which could only be appreciated and followed up by an engineer in constant touch with the practical application of these new principles.

That Mr. Seaton has fully realised this is very evident from the present edition, as, by comparing it with former ones, we find most of the chapters modified and extended, some entirely rewritten, a great many new illustrations added, others replaced by more modern ones, and a great deal of new text, with new illustrations, showing the very latest developments.

Thus, in former editions, triple and quadruple expansion engines were treated very briefly, and only general outline plans of them were given in an appendix, while in the present edition they are recognised as the standard types, and their theory, general construction and details fully elaborated and illustrated, while other types, which in former editions were spoken of in the present tense, are now only briefly alluded to in the past tense, showing that they have become obsolete.

Without the use of complicated formulas, or higher mathematics, Mr. Seaton shows very plainly, step by step, how the economy of compound, triple and quadruple expansion engines is obtained, both by the use of higher pressures and by successive steps in expanding steam in two or more cylinders, adding examples and a number of tables derived from practical construction. In further chapters all the details are successively treated, with formulas, examples and tables for their proper proportion and construction.

In Chapters 17 and 18, the theory of boilers and their design is treated, and a number of new illustrations and tables have been added here. Chapter 19, treating of water-tube boilers, is entirely new, and this type, now becoming more important, is described at length, with numerous fine illustrations. Of special interest to American engineers may be noted that Col. Stevens, of Hoboken, is mentioned as one of the first to construct and work successfully a water-tube boiler as early as 1805, and many may have seen this curious relic, in connection with machinery for a twin-screw boat, at some of the exhibitions held lately. Among other boilers of this type, the Herreshoff and the Babcock and Wilcox are described and illustrated; also, the Belleville, fitted in many French steamers, in the Great Northern Company's large passenger steamers on the lakes, and in the latest British cruisers *Powerful* and *Terrible*.

The remaining chapters are devoted to details of boiler construction, their

mountings and fittings, to details of engine equipment, materials, a number of useful tables, giving weights of machinery, results of trials, and, finally, the different rules for boilers and machinery prescribed by Lloyd's Register, the British Board of Trade, etc.

All these matters are presented in an eminently practical manner, with formulas of the simplest kind, rendering this work exceedingly useful to the practical constructing engineer and his assistants in the drawing office, as well as to ship owners, consulting engineers and others in this line, who sometimes have to get outlines of ship designs, estimates, etc., at short notice. J. H.

Valve Gears for Steam Engines. By Cecil H. Peabody, Associate Professor of Steam Engineering at the Massachusetts Institute of Technology. New York: John Wiley & Sons. 1892. Pp. 128, with 33 plates. (Price, $2.50.)

The author, in the preface, clearly points out that the aim of the book "is rather to give the beginner a firm grasp of the principles and some facility in their application," than an exhaustive treatment of the many gears in use at present.

In Chapter I he describes the parts of the valve gear of a slide valve engine, and deduces the equation for the movement of the valve in terms of the constants of the gear and the movement of the crank. After explaining the use of the valve ellipse and the sinusoidal diagrams of Moll and Moutéty, the diagram proposed by Zeuner is shown to agree with the valve travel on the assumption of harmonic motion for the valve. This form of diagram is used almost entirely throughout the book, because "it is widely and favorably known, and appears to the author to be be at least as good as any other circular diagram." The events of the stroke are next traced out, together with the effects upon them of changes in various parts of the gear. Besides several problems in valve design, the equalizing of cut-off on both ends of the cylinder by means of a rocker arm is given with a few methods of valve setting.

Chapter II considers adjustable eccentrics; showing first, by means of the Zeuner diagram, the effects of turning loose eccentrics on the shaft, or changing the position of movable eccentrics giving variable lead. This naturally leads to gears for shaft governing, and, as an illustration, the Straight Line governor is shown, the Zeuner diagrams for which clearly show the results obtained by moving the eccentric across the shaft. The Armington & Sims governor is also illustrated after the shifting eccentric with constant lead is dealt with.

The first part of Chapter III contains the description and analytical discussion of Stephenson and Gooch links. Their uses and distinctive features are explained and illustrated by drawings. The latter part of the chapter shows the method for equalizing cut-off and reducing slip by means of selecting proper positions for the hanger and reverse shaft, and explains the use of a skeleton model in designing gears and determining the effects produced by changes in the different members of the motion. The skeleton model will be

found useful in this field of work, although the same thing has been accomplished with more labor by the use of the link template. The method of setting a link motion is given, together with the results of varying the position of the saddle pin, length of link, point of attachment of rods, or the position of equalised cut-off, thus putting before the student facts which will be useful in practice.

Radial gears are defined and explained in Chapter IV. The Zeuner diagram for the Walschaert gear is worked out, although for the Marshall gear the valve ellipse is used. The Joy gear is illustrated, and this, with the illustrations for the former two, gives the student an idea of the gears as they appear in practice.

Chapter V treats of the methods used to obtain early cut-off by means of an auxiliary valve working on a separate seat, or on the back of the main valve. The variation of cut-off, due to shifting the eccentric or changing the lap or clearance, is shown by means of the Zeuner diagram. The method for designing and setting a Meyer valve is given, and an arrangement of eccentrics for changing the cut-off, without altering the relative movement of the valves, is worked out and explained.

In the last chapter, drop cut-off gears are described, using as examples the Brown, Corliss, Putnam, and Gaskill gears. The action of these gears is developed and the peculiarity of their design pointed out. The use of the valve ellipse for the Corliss gear is shown, and the action of the gear, when the governor is down, is explained.

The book, as a whole, is practical, uniting with the text examples from the present practice, and although, as the author says, it does not cover or attempt to cover the whole field of valve gears, it gives the student a working knowledge of the common gears, so that he may of himself be able, with little effort, to work out such gears as may present themselves. The plates in the book are of high order and illustrate fully the matter of the text. A. M. G.

Compend of Mechanical Refrigeration: A Comprehensive Digest of Applied Energetics and Thermodynamics for the Practical Use of Ice Manufacturers, Cold Storage Men, Contractors, Engineers, Brewers, Packers, and others interested in the application of Refrigeration. By J. E. Siebel, Director Zymotechnic Institute, Chicago. Chicago: H. S. Rich & Co. 1895. (Price, $2.50.)

Aside from the elaborate works on thermodynamics, treating of the scientific principles underlying the practice of mechanical refrigeration, and which are of the nature of mathematical treatises altogether too abstruse for the comprehension of those engaged in operating refrigerating machinery, the literature of this subject, at least that which is available in the English, is meager. The multiplication of uses for refrigerating machinery in ice-making, cold storage, brewing, etc., of late years has been astonishingly great, and the need for a practical treatise on the subject, which should present the various phases of the case in a manner readily adapted to the comprehension of those engaged in these industries, has been urgently felt.

The present work meets this requirement very satisfactorily. The use of mathematics has been confined to what is really necessary as a labor-saving device in making calculations, and the elucidation of the principles involved in the subject is made so clear that no intelligent engineer or manufacturer should fail to follow the author in his treatment of the subject.

The numerous physical tables and problems appended to the work add greatly to its value. W.

The Mechanical Engineers' Pocket-Book. A reference book of rules, tables, data, and formulæ, for the use of engineers, mechanics and students. By William Kent, A.M., M.E., etc. New York: John Wiley & Sons, 53 East Tenth Street. 1894. 12mo, morocco flap. (Price $5.)

Mr. Kent has given the mechanical engineering fraternity a pocket-book which will take its place as a companion volume to Trautwine's incomparable pocket-book for the civil engineer. It is thoroughly "up-to-date" and exhaustive. The publishers have done their part of the work irreproachably. W.

The Chronicle Fire Tables for 1895.—Being a record of the fire losses in the United States and Territories during 1894, etc. Royal 8vo. New York: The Chronicle Company, Limited. (Price, $5.)

This remarkable series of tabulations comes rather later than usual, due, undoubtedly, to the increasing labor required for such work in its larger size. The fire losses of 1894, as here reported ($140,000,000), show a diminution, as compared with 1891, of $4,000,000; with 1892, of $12,000,000, and with 1893, of $28,000,000. This is cheering news to property owners and fire insurance companies. It is probably largely due to the care now insisted on by the fire underwriters' associations, and the improved supervision and inspection of risks by them and by insurance companies. It has also been aided by the much larger use of non-ignitible roofs and general improved modes of building.

This volume bears on its face evidence of that accuracy for which all its predecessors have been noted, giving, among others, an alphabetical list of fires, by causes; summary of fire losses in the United States, by causes; risks burned in said country during twenty years—1875-1894—by principal causes, besides many other valuable tabulations. The principal fires which occurred during 1894, with description of property and approximate losses, are given separately; also summaries of fires, losses and causes, by risks (148 tables), showing aggregate and average losses, proportion of fires originating on or off the premises, and causes of fires—all in alphabetical arrangement.

There is at the end, besides a full index, a valuable essay on "The Legal Status of the Insurance Agent under the Law of Agency," by the late J. Griswold, an eminent insurance expert and statistician. No wonder that the volume has swelled to 395 pages. It gives so much valuable information in

concise form, that the price should be considered low by fire insurance companies, attorneys-at-law and all careful property owners. The heavy paper, and solid, handsome binding, are all that could be desired.

N.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, October 16, 1895.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 16, 1895.

JOS. M. WILSON, President, in the chair.

Present, 113 members and 16 visitors.

Additions to membership since last meeting, 5.

The Secretary called attention to a circular-letter received from the Institution of Civil Engineers of London, transmitting a list of subjects for papers selected by the Council of the Institution as desirable themes for original communications, and, for meritorious contributions to which the Council is empowered to award premiums arising out of special funds bequeathed for the purpose.

Mr. Alfred F. Watch described an invention of M. Ducos du Hauron, called the Anaglyph, and which may be defined briefly as a novel photographic method of obtaining the stereoscopic effect. Mr. Watch illustrated his paper by the exhibition of a number of specimens of the work. (The paper will appear in the December impression of the *Journal*.)

Mr. W. N. Jennings exhibited and commented on a series of flash-light photographs, taken by himself in the caisson at present in use for preparing the foundation for one of the channel piers of the Delaware River bridge.

Dr. Robert Grimshaw exhibited and described a compound test indicator, made by the Bath Indicator Company, of Hyde Park, Mass.; also, an improved tool for backing-off milling cutters, the invention of Mr. S. M. Balzer, of New York; and an improved lathe tool holder, manufactured by Armstrong Brothers, of Chicago.

The Secretary presented his monthly report, an abstract of which appears in the *Journal*.

Adjourned.

WM. H. WAHL, *Secretary*.